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CONTENTS

ASAOKA, O.: Distribution of *Melosira sulcata* (EHRENBERG) KÜTZING, a diatom species, in the seas west of Japan 1

KANO, Y.: The annual variation of the temperature, salinity and oxygen content in the Japan Sea 15

NISHIYAMA, K., S. KONAGA and H. ISHIZAKI: The cold water eddy observed far south of Shikoku in September 1979 27

KONAGA, S., K. NISHIYAMA and H. ISHIZAKI: Geostrophic transport in the East China Sea and southeast of Yakushima Island—A case study 33

Note

Oceanographical Division, Japan Meteorological Agency: The standard deviations of monthly mean sea surface temperature in the western North Pacific 41

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投稿規定

1　資　格

原則として，気象庁職員に限る。ただし，気象庁職員との連名の場合は，この限りでない。

2　論文及び報文（以下「論文等」という。）の内容

未発表の原稿で，海洋（物理・化学・生物・地質など）及び海上気象（波浪・海氷・海気相互関係など）に関する論文並びに気象庁における海洋・海上気象業務の活動，そのために開発された測器及び方法に関する報文など。

3　書き方

(1) 用語は，欧文（原則として英文）とする。

(2) 論文等には，英文（300語以内）及び和文（800字以内）の要約を付ける。要約は，方法・測器・実験・観測の結果・仮定・理論などの中味が読みとれるように留意し，なるべく指定の長さで簡潔に書く。

(3) 論文等の始めには，題名・著者名及所属機関名を明記する。和文の要約にも同様のことを明記する。

(4) 原稿は，厚手の用紙にダブルスペースでタイプする。

(5) 図は，白紙又は青方眼紙に墨入れし，図及び図中の文字の大きさは，印刷の際の縮小率を考えて作成する。特に重要な図は，投稿者が大きさを指定する（印刷の都合上，希望どおりにならないこともある。）

(6) 図（写真を含む。）及び表には，必ず説明を付ける。図の説明文は，別紙にタイプする。折り込みの図及び表は，なるべく避ける。図及び表のそう入箇所を本文の欄外に記入する。

(7) 数式は，2行取りに書き，数式の文字及び記号をはっきりと説明する。

(8) 論文等の中に文献を引用する場合は，「ALLEN (1927)」又は「(ALLEN, 1927)」のように書く。

(9) 引用文献は，最後にまとめて付け，著者名のアルファベット順に並べる。書き方は次のようにする。

ALLEN, W.E. (1927): Surface catches of marine diatoms and dinoflagellates made by U.S.A. Pioneer in Alaskan waters in 1923. *Bull. Scripps Inst. Occanogr., Tech. Ser.* 1(4), 39–48.

BUDYKO, M. I. (1956): *The heat balance of the earth's surface.* Hydrometeorogical Publishing House, Leningrad, pp. 254.

VERONINS, G. and H. STOMMEL (1956): The action of a variable wind stress on a stratified ocean. *J. Mar. Res.*, 15(1), 43–75.

4　提出方法

投稿票を付け，本稿のほかにコピー（図及び表を含む。）2部を添える。

5　締切り

毎年気象庁公報により公示する。

6　送付先

気象庁海洋気象部海洋課

（原則として，書留便で送付する。）

7　その他

論文等1編につき別刷り50部を著者に無料で送付する。

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Distribution of *Melosira sulcata* (EHRENBERG) KÜTZING, a diatom species, in the seas west of Japan

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(Received December 24, 1979; Revised January 21, 1980; Accepted January 24, 1980)

Abstract: An ecological study of *Melosira sulcata* is made in the continental shelf area of the East China Sea and the Yellow Sea during the years from 1960 to 1963.

1) *M. sulcata* are densely populated only in the bottom water together with dense floating silt in the warm period, while in the cold period the species and floating silt appear in all depths. The area where *M. sulcata* is present is restricted to the central part of the East China Sea in both seasons.

2) In the warm period, the bottom water area of the central part of the East China Sea, where *M. sulcata* and floating silt are present in large quantity corresponds to an area of the stagnant bottom water which locates in the center of a large anticlockwise circulation. The surface of the sea bottom here is covered with very fine sand.

3) In the central part of the East China Sea, the transparency of water in winter is low, being about half the value of Secchi disc reading in summer, and it may be due to the turbid bottom water upwelled to the surface by the winter vertical mixing.

1. Introduction

The present studies are intended to get the distributional patterns of *Melosira sulcata*, a diatom species, in the East China Sea and the Yellow Sea, and investigate the relationship between the characteristic distributions of the species and the hydrographic conditions.

The most part of the Yellow Sea and about two thirds of the East China Sea are occupied by the continental shelf areas, with depths shallower than 100 m. And these areas are covered by so-called the Continent Coastal Water of a considerably lowered salinity owing to dilution by runoff from the large Chinese rivers. On the other hand, the warm and saline Kuroshio Water flows toward the northeast along the outer edge of the continental shelf, and consequently the steep horizontal gradients of density appear in the waters between the Continent Coastal Water and the Kuroshio Water (Fig. 1). In the shelf area of the East China Sea, in winter, intence mixing of water by processes of convection and functions of wave extends from the surface to the bottom. On the other hand, in summer the density stratification is very stable, so the bottom water can hardly diffuse into the upper layer.

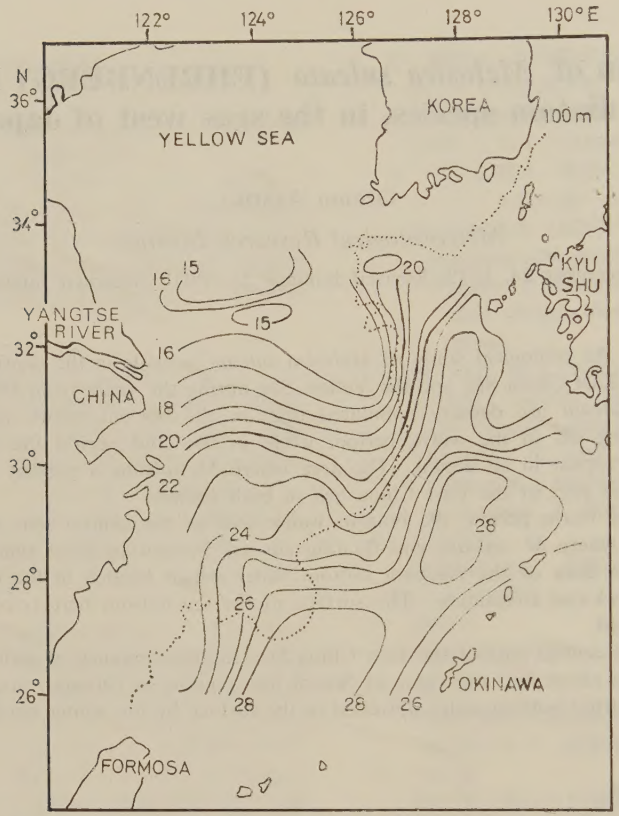

Fig. 1. Distribution of mean water temperature of the surface layer between the surface and 75 m depth in the East China Sea in July 1956. The values in the areas shallower than 75 m are averaged from the surface to the bottom (KATO, 1958).

Melosira sulcata (EHRENBERG) KÜTZING is a neritic or littoral water species and is benthic. It occasionally occurs as a plankton (tychopelagic), but under the planktonic life it can hardly increase sufficiently. However in some cases, it appears abundantly in the coastal waters (CUPP, 1943; BRUNEL, 1962). In Japan, although the occurrence of *M. sulcata* has been observed in coastal regions throughout the year, the large populations of the species are found especially in winter (KOKUBO, 1955).

2. Material and method

Sea water samples were taken at several depths from the surface to the bottom by

the R. V. Chofu-maru of the Nagasaki Marine Observatory, during her seven cruises of the routine oceanographic observations in the East China Sea, the Yellow Sea and the Kuroshio from 1960 to 1963.

For collecting the microplankton and processing the material in the laboratory for the purpose of accurate quantitative studies, the standard method which is detailed by Marumo (1954) was employed; shortly, the diatom samples contained in 500 ml of water are concentrated by decanting and later by centrifugalizing; identification and counting are made under microscope by aid of counting slide glass.

3. Distribution of *Melosira sulcata* in the warm period

1) Vertical distribution of *Melosira sulcata*

The oceanographic observations and the collections of plankton samples were made at nine stations along the isobath of 100 m in the central part of the East China Sea in August 1961 (Fig. 6D). The vertical distributions of the total cell numbers of diatoms per liter of water and the diatom communities at nine stations are shown in Fig. 2.

The four stations A7, A5, C8 and C6 are located at the outer boundary of the Continent Coastal Water as shown in Fig. 1. The clear surface water shallower than 20 m at these stations is characterized by the paucity of total diatom populations and by the simplicity of diatom communities mainly composed of the warm water species, such as *Rhizosolenia acuminata, R. alata, R. castracanei, R. imbricata* v. *shrubsolei* and *R. stolterfothii.* Below the clear surface water, a thin layer is observed at a depth of 20–30 m, where the water is characterized by the absence of diatoms as well as by the presence of the large amount of detritus in suspension. On the other hand, the bottom water deeper than 50 m is characterized by a large quantity of silt in floating and the monotonous presence of *M. sulcata,* being $5 \cdot 10^2$ to 10^3 cells per liter of water. At three stations I8, I6 and G11, located south of the aforementioned stations, the thin layer below the clear surface water is obscure, though a relatively large number of *M. sulcata,* being $5 \cdot 10^2$ cells or so, and abundant floating silt are also present in the bottom water. In the bottom water at stations G7 and G9 located in the Kuroshio areas, *M. sulcata* is entirely absent and instead of the species other diatoms, such as *Actinoptychus undulatus* and *Thalassionema nitzschioides* are present but in small number, being about 50 cells. However, floating silt is present near the bottom in considerable quantity.

A large amount of floating silt, being 5.0 mg of suspended solid per liter of water in the maximum, is found at the stations (St. A2-5, B7) along 32°N as shown in Fig. 3 and it decreases in quantity from the inner part of the shelf areas to the outer

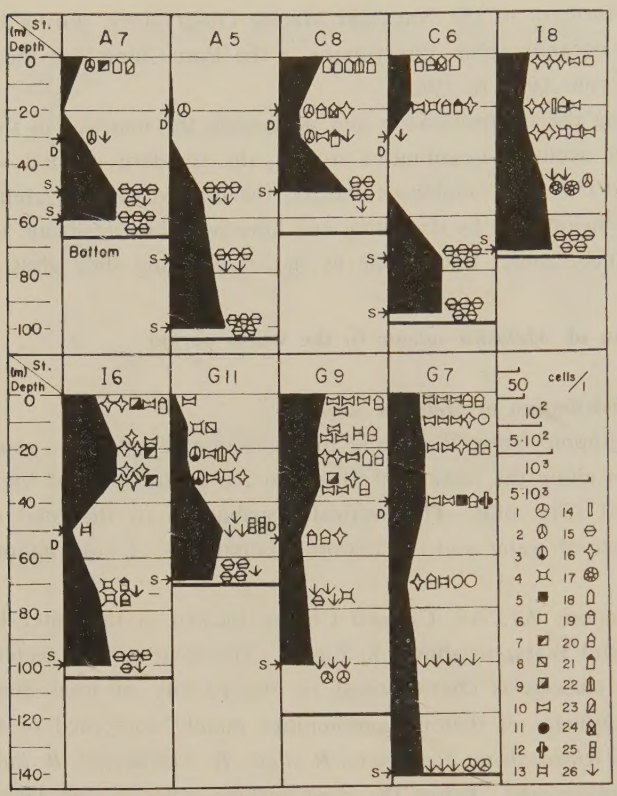

Fig. 2. Vertical distributions of total numbers of diatoms and the diatom communities in August 1961. Arrows denote the depths where detritus (D) and floating silt (S) are observed. Locations of the stations are shown in Fig. 6D. Symbolized figures represent the important diatom species. Each figure approximately corresponds to 20 percent of total diatoms in occurrence. Specific names represented by the figures are given: 1. *Actinoptychus undulatus*, 2. *Asteromphalus flabellatus*, 3. *A. cleveanus*, 4. *Chaetoceros atlanticus* v. *neapolitana*, *C. coarctatus*, *C. dadayi*, *C. tetrastichon*, 5. *C. constrictus*, 6. *C. holsaticus*, *C. laevis*, 7. *C. compressus*, 8. *C. didymus*, 9. *C. radicans*, 10. *Climacodium biconcavum*, 11. *Coscinodiscus curvatulus*, *C. excentricus*, 12. *Dactyliosolen mediterraneus*, 13. *Hemiaulus hauckii*, 14. *Leptocylindrus minimus*, 15. *Melosira sulcata*, 16. Pennatae misc., 17. *Planktoniella sol*, 18. *Rhizosolenia acuminata*, *R. castracanei*, *R. imbricata* v. *shrubsolei*, 19. *R. alata*, 20. *R. calcar avis*, 21. *R. setigera*, 22. *R. stolterfothii*, 23, *R. styliformis*, 24. *R. styliformis* v. *latissima*, 25. *Skeletonema costatum*, 26. *Thalassionema nitzschioides*.

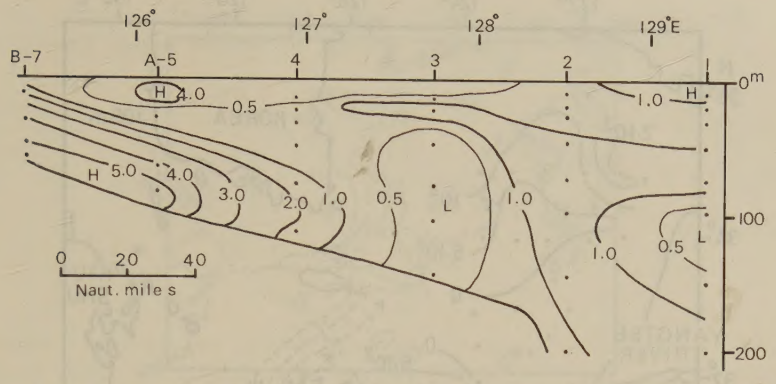

Fig. 3. Distribution of suspended solid (mg/l) in the section along 32°N in August 1970 (N.M.O., 1970).

edge of the shelf.

2) Horizontal distribution of *Melosira sulcata*

To obtain the horizontal distributional patterns of *M. sulcata* in the bottom water during the warm periods, the quantitative data on *M. sulcata* of the collections from May to September in 1960–1963, are plotted on the Fig. 4. The two large populations of the species, being more than 10^3 cells per liter of water, are found; one is in the central part of the East China Sea (31°N, 126°E), and the other is in the western part of the Yellow Sea (35°N, 121°E). On the other hand, the species is entirely absent in the area northeast of the mouth of the Yangtse River which locates between the two areas mentioned above. On the distribution of suspended solid in the bottom water in the central part of the East China Sea in August 1970 (Fig. 5), the area with dense floating silt more than 1.0 mg of suspended solid per liter of water is in accord with the densely populated area with *M. sulcata* more than $5 \cdot 10^2$ cells (Fig. 4).

4. Distribution of *Melosira sulcata* in the cold period

During November to March, the mixing of water takes place from the surface to the bottom and consequently the plankton organisms and the floating silt which are present in the bottom water in summer are observed at all depths. Therefore in the cold period, the surface distribution of *M. sulcata* can be seen in the waters of the shelf areas as shown in Fig. 6. The locations of the densely populated area with the species at the surface in cold periods are similar to those of the bottom area where *M. sulcata* occur in large number in the warm periods (Fig. 4).

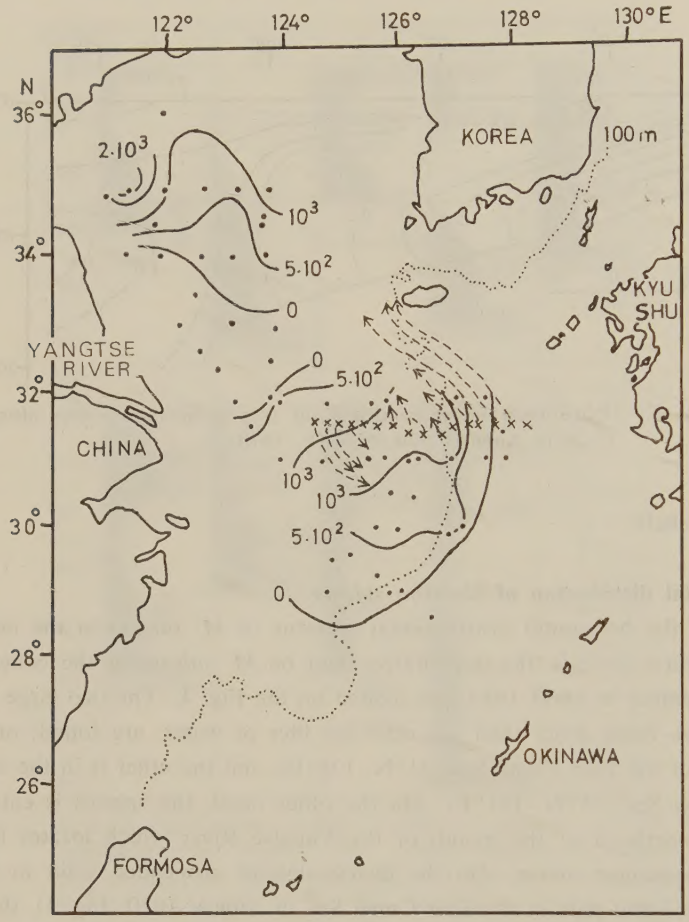

Fig. 4. Distribution of *Melosira sulcata* (cells/l) in the bottom water of the shelf areas during warm periods in 1960–1963. The crosses in the figure denote the release positions of the sea-bed drifters and the trajectories of the drifters (broken line) in November 1969.

5. Discussion

1) Vertical distributions of *M. sulcata* both in summer and winter at the stations near 32°N, 126°E in the shelf area are shown in Table 1. In summer, the diatom communities in the bottom water are composed of the nearly monotonous presence of *M. sulcata*, occupying more than 90 percent of the total number of diatoms, while

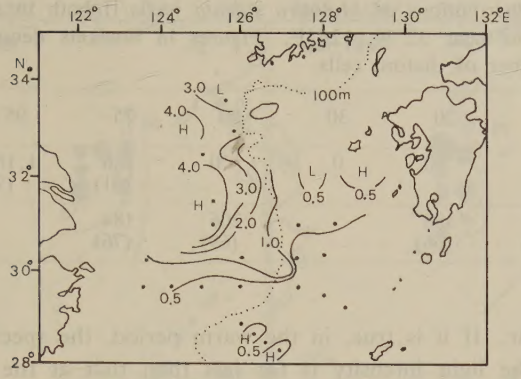

Fig. 5. Distribution of suspended solid (mg/l) in the bottom water in August 1970 (N.M.O., 1970).

in winter *M. sulcata* prevails through the vertical range of water column from the surface to the bottom. *M. sulcata* decreases gradually in number downward in winter, and at some stations the species is entirely absent in the bottom water.

A large quantity of floating silt as well as the richness in *M. sulcata* is also observed at the surface in winter, and accordingly the surface distributions of *M. sulcata* coincide with the turbid water of less than 10 m of Secchi disc reading. Moreover, the outer boundary of the surface distributions of *M. sulcata* are closely related to the discontinuity zones of the transparency and the water color, and to the surface isotherm of 15°C (Figs. 6A-C). From the water mass analysis by Kato (1959), the isotherm of 15°C at the surface in winter represents the boundary between the Kuroshio Water and the Continent Coastal Water.

As shown in Fig. 6D, the 10-m contour of transparency in March and the 20-m contour in August in 1961 are close to each other, and at the stations in the shelf area, the transparency of water in March is about half the value of that in August (Table 1). It has been supposed that such less transparent water in winter is much influenced by the runoff from large Chinese rivers. However, from the seasonal variations of *M. sulcata* in occurrence both in the surface water and in the bottom water, as well as the vertical distributions of floating silt in summer and winter, it seems that the turbid water may be caused by the vertical mixing of water in cold seasons.

2) In the central part of the East China Sea *M. sulcata* change their living depths seasonally, however the area where the species is present is restricted to a certain area

Table 1. Vertical distributions of *Melosira sulcata* (cells/l) both in summer and winter at the stations near 32°N, 126°E. Figures in brackets denote percentages of the total number of diatom cells.

Depth (m)	0	20	30	50	75	95	Transparency (m) Water Color
Aug. 1961	0	0	0	0	986 (91)	1,188 (93)	20 3
Mar. 1962	650 (74)	388 (66)		206 (69)	184 (76)		7 6

throughout the year. If it is true, in the warm period, the species is obliged to live at depths where the light intensity is far less than that at the usual compensation depth (SAIJO *et al.*, 1969) owing to the heavy turbid bottom water.

The measurements of photosynthetic rate and light intensity were made by SAIJO *et al.* (1969), from May to June in 1968 in the central part of the East China Sea. From the results of their experiments, it is recognized that *M. sulcata* evidently multiplies under the condition of very low illumination as low as 100 lux.

HELLEBUST and GUILLARD (1967) also showed experimentally, that marine diatom species *Melosira nummuloides* support growth of a cell in the absence of light by their heterotrophic ability of uptake of particulate organic substrate. Then it is assumed from the above-mentioned facts that in the warm period *M. sulcata* can live in the dim bottom water of the central part of the East China Sea.

3) It is said that the Tsushima Current flows northward in the sea west of Kyushu and that its branch enters the eastern part of the Yellow Sea. The Yellow Sea is considered to be closed at the northern end and there must be a southward transport equal to the amount of the inflow due to the Tsushima Current. In other words, it is natural that an anticlockwise circulation is formed in the region. ASAOKA and MORIYASU (1966) considered the existence of the circulation which extends over the East China Sea and the Yellow Sea from the distributions of temperature and plankton diatoms in the surface water in the winter of 1963. They showed that NW winter monsoon can develop the anticlockwise circulation and presumed also that the water in the center of the circulation is stagnant and it is always localized in the central part of the East China Sea.

In November 1969, the measurements of the bottom current in the central part of the East China Sea were made by the Seikai Regional Fisheries Research Laboratory. The trajectories of sea-bed drifters are obtained by connection between the release points of drifters along 31.5°N and the recovery points of them within 60-days drift (KAWAI *et al.*, 1970). The release positions of drifters are situated near the center-line

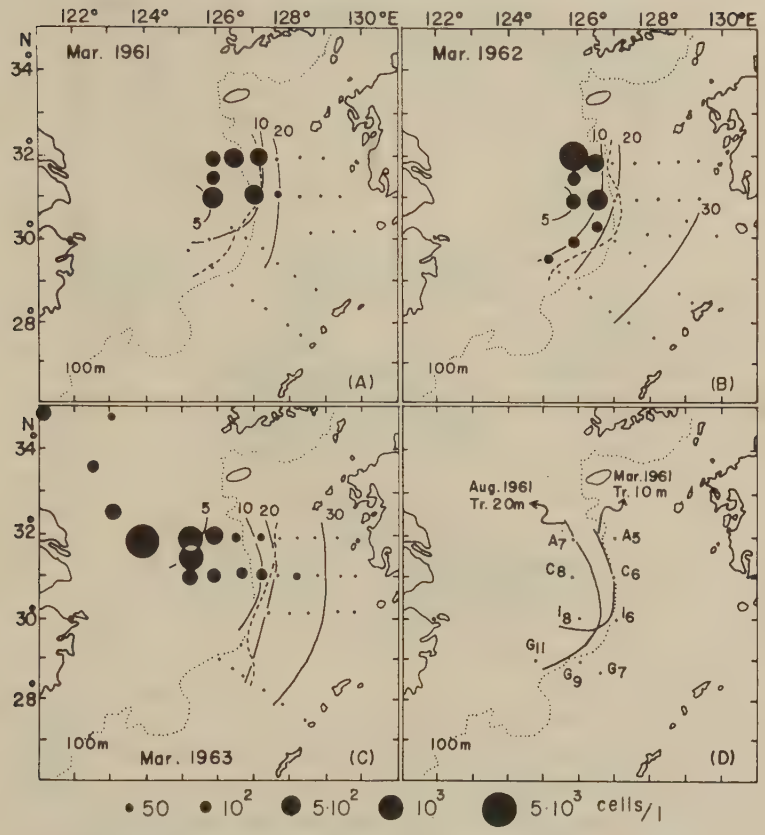

Fig. 6. Surface distribution of *Melosira sulcata* in March in 1961–1963. Solid line (A–D): contour line of transparency in meter. Broken line (A–C): 15°C isotherm at the surface.

of the aforementioned anticlockwise circulation. It is supposed from the trajectories of sea-bed drifters that the bottom current circulates in anticlockwise sense, and the speed of current is fast at the edge and slow at the center (Inoue, 1975, Figs. 4 or 7).

It is clear from the present study that a large quantity of *M. sulcata* and suspended solid are observed in the circulating bottom water. In addition, from the distribution of very fine sand which is represented by percentage of terrigenous deposit whose particle is less than 0.122 mm in diameter (Hamada *et al.*, 1962; Fig. 7), a large quantity of very fine sand, being 80 percent, is observed at the central part of the circulation.

Now, tidal current is probably the strongest in such a shallow sea, but besides this, permanent currents reaching to the bottom may exist which will carry the suspended

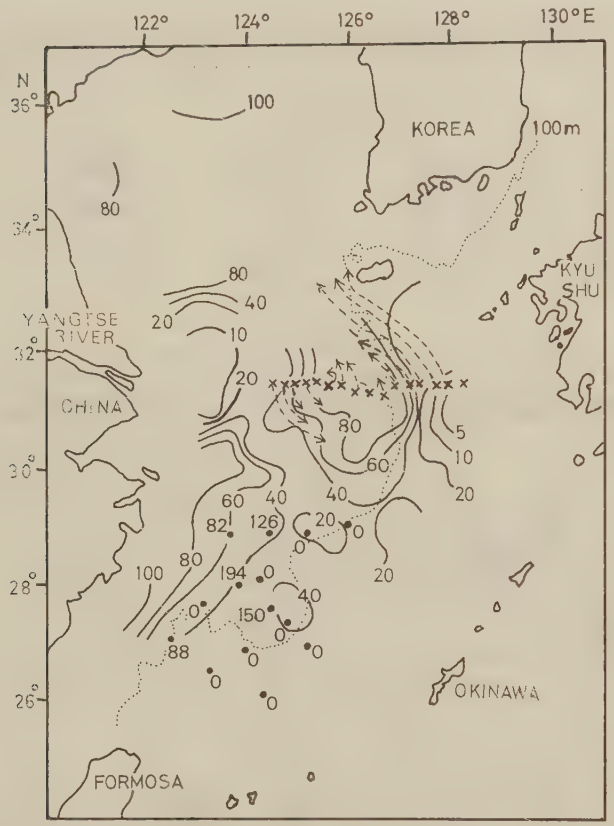

Fig. 7. The distribution of very fine sand on the sea floor represented by percentage (HAMADA *et al.*, 1962), and surface distribution of *Melosira sulcata* (cells/l) in winters of 1966 and 1967. Explanation of the crosses is the same as in Fig. 4.

solid away. In the area investigated the supply of fine material is great, so the particles can then accumulate only where the deposition is greater than transportation (SVERDRUP *et al.*, 1942). Therefore, in the region with a large quantity of very fine sand and of suspended solid near the bottom the current may be so small in speed.

4) In the coastal region, it has been studied by many investigators that the benthic marine diatoms make change of their size and composition according to whether they live in silty or sandy bottoms (ROUND, 1971). From the distributions of very fine sand on the sea floor in the shelf area (Fig. 7) and of *M. sulcata* in the bottom water in the

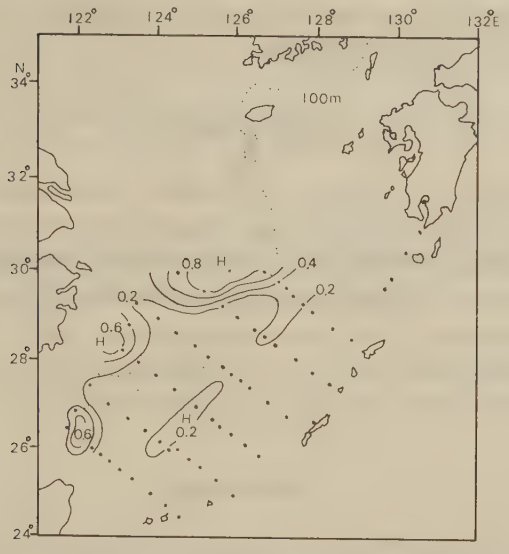

Fig. 8. Distribution of phosphate-phosphorus (μg-at/l) at a depth of 50m in October 1973 (J.M.A., 1975).

warm period (Fig. 4), it is recognized that the densely populated area with the species in the East China Sea and the Yellow Sea corresponds to the bottom areas covered with a large quantity of very fine sand whose particle is less than 0.122 mm in diameter. On the other hand, in the bottom water northeast of the mouth of the Yangtse River, *M. sulcata* is entirely absent, where the bottom is covered with medium sand and a small amount of very fine sand, being less than 20 percent. Accordingly it is suggested that the distribution of the species in the bottom water is closely related to that of the particle size of terrigenous deposits on the sea floor.

5) In January in 1966 and 1967, the surface distribution of *M. sulcata* in the southwestern area of the East China Sea was obtained as shown in Fig. 7. There is no data of plankton in the bottom water in the warm period here, but the area may be the other densely populated area with *M. sulcata* than the two areas both in the central part of the East China Sea and in the Yellow Sea as shown in Fig. 4.

The environmental conditions of this southwestern area of the East China Sea are closely resemble to those in the central part; the sea floors of both areas are covered with a large amount of very fine sand (Fig. 7) and the waters deeper than 50 m in both areas are cold and rich in phosphate-phosphorus (Fig. 8). Consequently,

it is assumed that this area may also correspond to the weak current area as mentioned in the central part of the East China Sea.

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The author appreciates the aid of the members of Oceanographical Division and the crew of the R. V. Chofu-maru of the Nagasaki Marine Observatory. And he is also grateful to Emeritus Prof. Otohiko TANAKA of the Kyushu University, Prof. Ryuzo MARUMO of the Tokyo University, Prof. Shigeru FUKASE of the Hokkaido University and Dr. Shigeo MORIYASU of the Japan Meteorological Agency for their helpful suggestions and encouragements, and to Dr. Yutaka KAWARADA of the Japan Meteorological Agency of his critical reading of this manuscript.

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西日本海域における，珪藻の一種 *Melosira sulcata* (EHRENBERG) KÜTZINGの分布

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1960年から1963年にかけて，東シナ海・黄海の大陸棚海域における *Melosira sulcata* の生態について研究した。

1) *Melosira sulcata* は暖候期には，濃い浮泥とともに低層水中のみに見出されるが，寒候期には全層に出現する。また本種と浮泥とは両季節ともに，東シナ海中央部のほぼ一定の海域に現われる。

2) 暖候期に *Melosira sulcata* と浮泥とが多量に存在する東シナ海中央部の底層水域は，その中心部に停滞域をもった反時計まわりの循環域と一致しており，また，その海域の海底面は very fine sand でおおわれている。

3) 東シナ海中央部では冬の透明度の値は低く，平均して夏の約半分であるが，それは多分，夏のにごった底層水が冬の鉛直混合によって表層にはこばれるためであろう。

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The annual variation of the temperature, salinity and oxygen content in the Japan Sea

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Abstract: A statistical study on the annual variation of sea water temperature, salinity and oxygen content in the Japan Sea was carried out using the seasonal data in the period 1973–1976.

It was revealed that the relation between the amplitude of the annual variation and the phase (the occurrence time of the maximum value), and the *stability* of the annual variation of each oceanographic parameter are good indicators to identify the waters into the four types; namely, the coastal warm water, the near coastal cold water, the Tsushima Warm Current water and the offshore cold water.

1. Introduction

Although the Japan Sea is a small marginal sea of the Pacific Ocean, the hydrographic structure is not simple and the subsurface layer is occupied by the several types of water mass as originated from the Tsushima Warm Current and the Liman Cold Current on the proper water which is characterized by 1°C in temperature and 34.1 per mill in salinity. Moreover, its surface and subsurface water has clear annual variation, particularly in water temperature.

As the first step to identify the annual and long-term variation of the oceanographic structure of the upper water of the Japan Sea, statistical studies on the oceanographic parameters were intended from the point of view of the annual variation. This paper was aimed to present the results of the statistical study on sea water temperature, salinity and oxygen content. TANIOKA (1962) investigated the seasonal variation of salinity at the sea surface and at the depth of 100 m in the Japan Sea and revealed the northeastward travel of the phase in their variations. In this study the vertical structure of the relation between the amplitude and the phase of the variation were discussed. The usefulness of the *stability* of the annual variations as the indicator of water masses was well demonstrated.

2. Data source and method

Since 1972, the hydrographic survey along the section in NW-SE direction has been

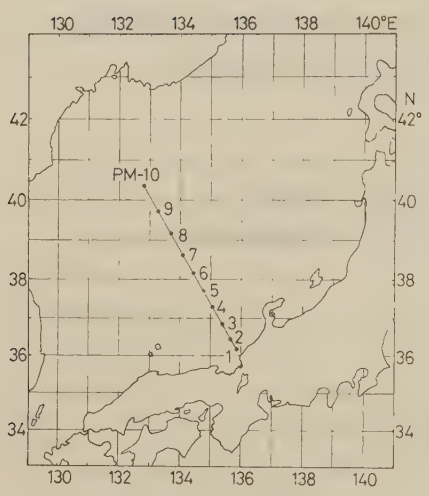

Fig. 1. Location of hydrographic stations.

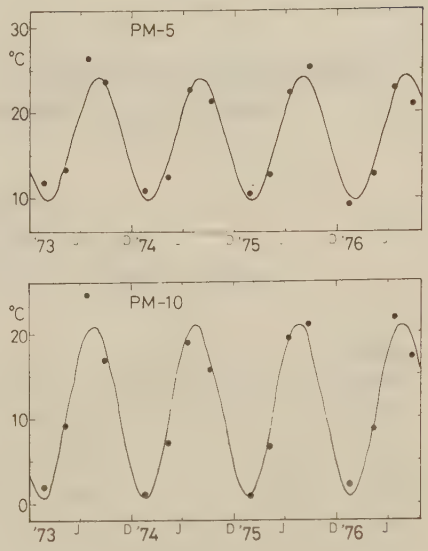

Fig. 2. Observed sea surface temperature and estimated annual periodic curve at PM-5 (upper) and PM-10 (lower).

carried out on board the Seifu-Maru, Maizuru Marine Observatory in the Japan Sea as a part of the Background Marine Pollution Monitoring Project of the Japan Meteorological Agency. As the survey has been conducted regularly in every season, it is convenient to analyse the annual variation of the oceanographic structure. The 10 hydrographic stations are located along the section of 300 miles. The section starts from PM-1 at 36°08′N and 135°51′E near the coast of Honshu Island and terminates at PM-10 at 40°20′N and 132°40′E as given in Fig. 1 to monitor the gross feature of oceanographical structure in the Japan Sea. The spacing of stations, sampling depth and the method of observations are almost the same for each cruise. The position is within 4 nautical miles at PM-1 through PM-4 and 8 nautical miles at PM-5 through PM-10 from the intended location.

In the present study, the data of water temperature, salinity and oxygen content in the period 1973–1976 are processed from the point of view of the annual march. The amplitude of the annual variation and its phase (the month of the occurrence of the maximum value) were determined for each oceanographic parameter at the IAPSO (International Association for the Physical Science of the Ocean) standard depths from PM-1 through PM-10 using the least square method. Namely, assuming simple harmonic variation, the i-th estimated $\hat{y}_i$ at the time t_i (months from January

in 1973) can be written as follows:

$$\hat{y}_i = c + r \cos \frac{2\pi(t_i - \delta)}{12} \qquad (1)$$

where c is the mean value, r the amplitude and δ the phase, respectively. To minimize the $S = \sum_i (\hat{y}_i - y_i)^2$, where y_i is observed value at t_i, the values of c, r and δ are determined. For example, the observed data and the estimated annual variation of sea surface water temperature at PM-5 and PM-10 are shown in Fig. 2.

3. Results and remarks

(A) Annual mean

The annual mean (as given c in the equation (1)) of each oceanographic parameter is summarized to identify the gross hydrographic feature as follows.

(a) Sea water temperature (Fig. 3)

The annual mean of water temperature ranges from more than 18°C through less than 12°C at the sea surface. In the upper layer at a depth of less than 75 m, the temperature gradually decreases northward. The definite thermocline is not seen except at PM-9 and PM-10. The 10°C isotherm lies at a depth of 150 m at PM-1 and PM-5, around 100 m at PM-3 and around 10 m at PM-10. The warm core, defined as a portion which temperature is higher than that of surroundings at a given depth, is located in the layer deeper than 100 m around PM-5.

(b) Salinity (Fig. 4)

Sea surface and near sea surface water is less than 34.0 per mill in salinity throughout the section, in particular, at PM-1 and PM-2 it is less than 33.7 per mill due to the coastal water effect. In the subsurface layer at a depth of around 100 m there exists the salinity maximum which ranges from 34.10 to 34.30 per mill in salinity except PM-10. The salinity at a depth of 200 m or more is almost constant ranging between 34.00 and 34.10 per mill.

(c) Oxygen content (Fig. 5)

The dissolved oxygen content gradually increases northward at every depth from the sea surface to deep layers. The oxygen content of sea surface varies from less than 6.0 ml/l to near 7.0 ml/l. The oxygen maximum layer is seen at a depth of 200 m to the south of PM-8 and a depth of 20 m to the north of PM-8. At PM-10 the maximum content exceeds 7.4 ml/l. The oxygen minimum layer lies to the south of PM-8 at the depth of around 75 m, where the oxygen content is less than 6.0 ml/l. At a depth of 75 m to 100 m between PM-4 and PM-6, there is the water less than 5.8 ml/l in oxygen content. This area is identical to that occupied with the water more than 34.25 per mill in salinity.

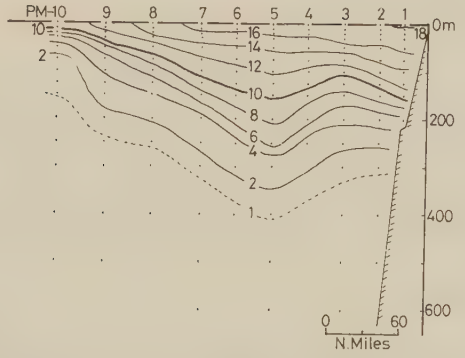

Fig. 3. Vertical distribution of annual mean temperature (°C).

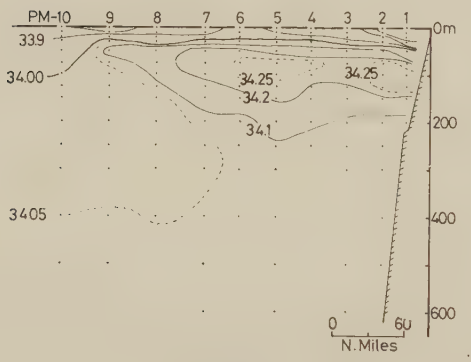

Fig. 4. Vertical distribution of annual mean salinity (per mill).

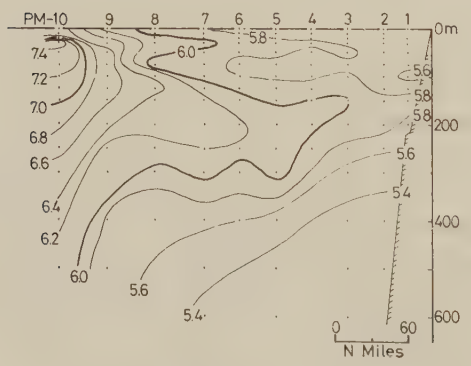

Fig. 5. Vertical distribution of annual mean oxygen content (ml/l).

(B) Amplitude and phase of the annual variation

The relation between the amplitude (range) of the annual variation and its phase (the month of occurrence of the maximum value) is useful to reveal the characteristics of annual march of the hydrographic structure. At first, the relation as given on the circle graph for the various depths at the two typical stations, PM-5 and PM-10, was studied.

(a) Water temperature (Fig. 6)

At the sea surface, the water temperature maxima are observed in September at PM-5 and in August at PM-10, respectively. The amplitude of the annual variation decreases almost exponentially and the phase delays near linearly with depth, as expected from the theory of thermal conduction. It is, however, noteworthy that the decrease of the amplitude with depth at PM-10 is more rapid compared with that at PM-5, whereas the delay of the phase with increasing depth is smaller than that of PM-5. This suggests the difference of the thermal properties of the ocean between the warm current region and the cold water region.

(b) Salinity (Fig. 7)

At PM-5 salinity is the maximum in spring at the sea surface and near surface. On the other hand, in the layer deeper than 100 m, the maximum is seen in fall. The amplitude shows good coincidence with the study of TANIOKA (1962), however, the results in his study indicates that the maximum is in June at a depth of 100 m.

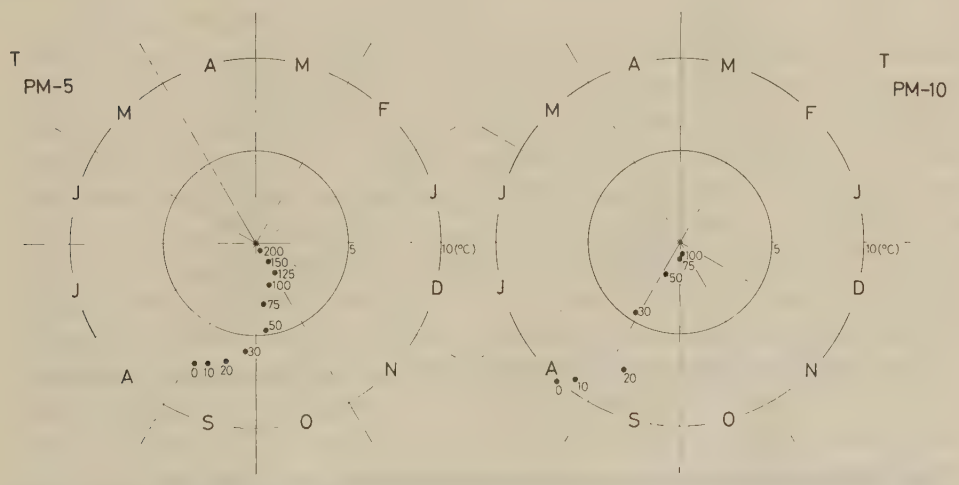

Fig. 6. Vertical change of relation between the amplitude (°C) and the phase (month of maximum temperature) of water temperature at PM-5 and PM-10. The numerals indicate the depths (m).

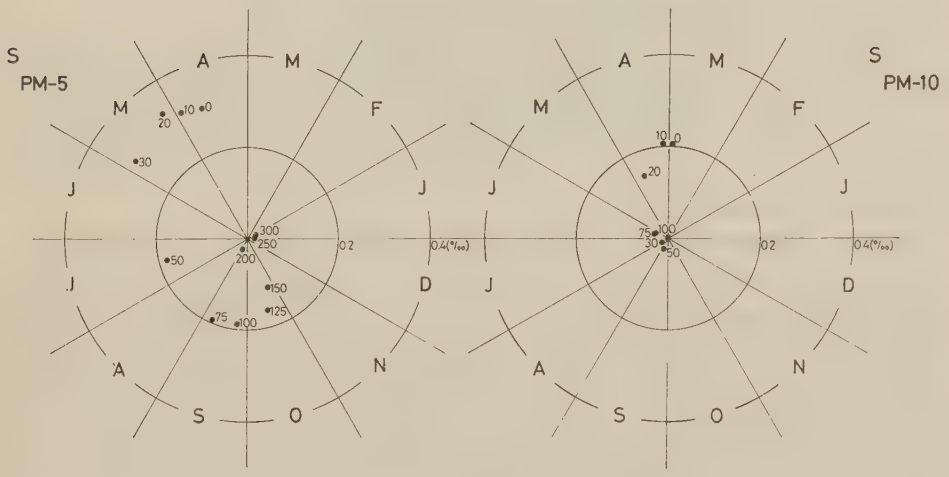

Fig. 7. Vertical change of relation between the amplitude and the phase of salinity at PM-5 and PM-10.

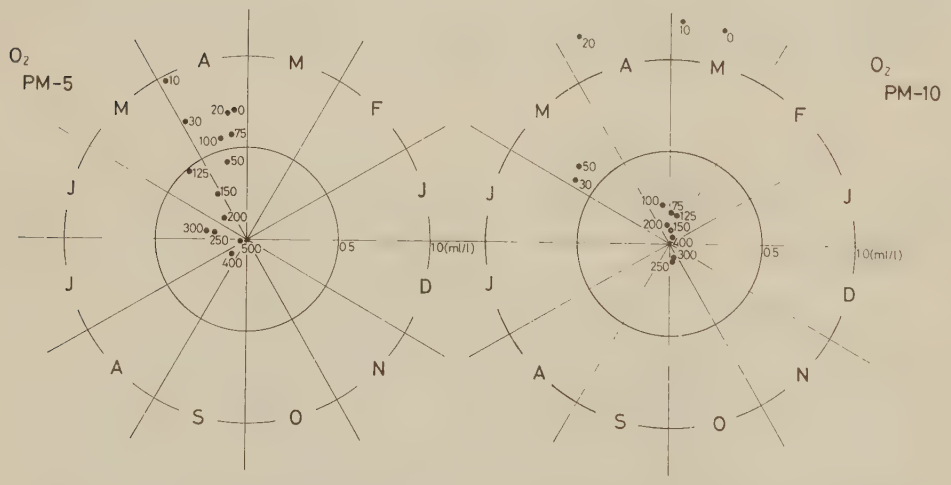

Fig. 8. Vertical change of relation between the amplitude and the phase of oxygen content at PM-5 and PM-10.

At PM-10 in the layer at a depth of sea surface to 20 m the maximum occurs earlier than that at PM-5. In the layer at a depth of more than 20 m the amplitude is very small and the delay of the phase is not obvious. In addition to those characteristics in

amplitude and phase, taking account of the fact that the salinity measured at the sea surface at PM-10 never exceeds 34.0 per mill even in spring, it could be explained that the haline water in spring at PM-10 is not originated from the Tsushima Warm Current but is probably originated from deep layer by vertical mixing in winter season.

(c) Oxygen content (Fig. 8)

At PM-5, the dissolved oxygen content is abundant in spring at a depth of sea surface to 150 m, whereas at PM-10 the annual range rapidly decreases with depth and the annual range at a depth of more than 50 m is smaller than that at the same depth at PM-5.

In the followings, the relation between the amplitude and the phase is studied from location to location at a few selected depths.

(a) Water temperature (Fig. 9)

At the sea surface, the annual range is the largest at PM-10 as a result of much cooling in winter season and relatively uniform warming through the section in summer season. Whereas, at a depth of 50 m the annual ranges at PM-9 and PM-10 are much smaller contrary to that at the sea surface. Around PM-9 and PM-10, the cold proper water of the Japan Sea occupies up to the shallow layers and this results in small annual range. At a depth of 50 m and 100 m, the relation between the amplitude and the phase at PM-3 is close to those at PM-9 and PM-10, and this shows that the cold type water also occupies the subsurface layer at PM-3.

(b) Salinity (Fig. 10)

At the sea surface, the annual range is large at PM-1 and PM-2, which are located close to the coast of Japan, and the annual range decreases northward. The large range at PM-1 and PM-2 is caused by supply of haline water in spring from the Tsushima Warm Current and low salinity water from the coastal area in fall. On the other hand, at PM-10 the annual range is small probably because the haline water from the Tsushima Warm Current in spring may not reach there. The difference in phase between the sea surface and a depth of 50 m through 100 m is larger at PM-4 through PM-8 compared with that at PM-1 through PM-3. The phases at PM-1 through PM-3, the coastal region, well correspond to the results by TANIOKA (1962), however, those between PM-4 and PM-8 delay much larger than that of his analysis.

(c) Oxygen content (Fig. 11)

At the sea surface, the annual range of dissolved oxygen content at PM-10 is much larger than those at the other stations and this could be explained by taking account of the large amplitude of temperature and relatively linear relation between saturated oxygen content and temperature. On the other hand, the phases are concentrated in

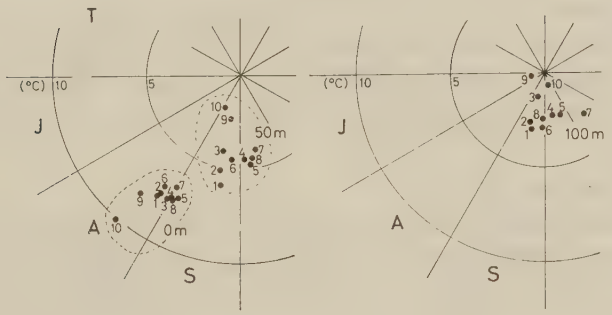

Fig. 9. Change of relation between the amplitude and the phase of water temperature from station to station at a few selected depths. The stations are shown by dots with numbers.

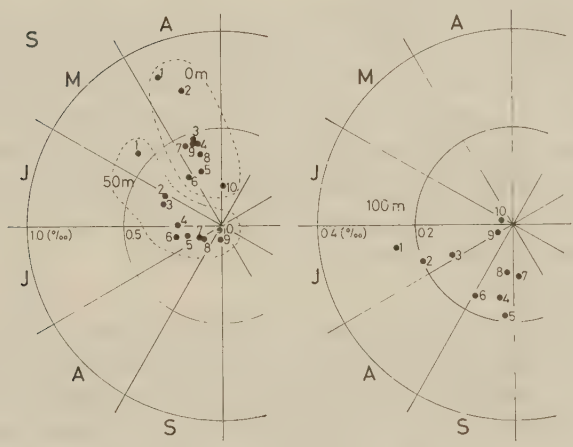

Fig. 10. Change of relation between the amplitude and the phase of salinity from station to station at a few selected depths.

March throughout the section.

At PM-9 and PM-10, the phases at a depth of 30 m through 50 m delay much larger than that at the sea surface. Because at the sea surface the variation of oxygen content mainly follows the variation of water temperature but at a depth of 30 m to 50 m the variation of oxygen content is affected by phytoplankton which increases in spring. This suggests that at PM-9 and PM-10 the increase of phytoplankton in spring may be delayed compared with that at the other stations due to low temperature in winter.

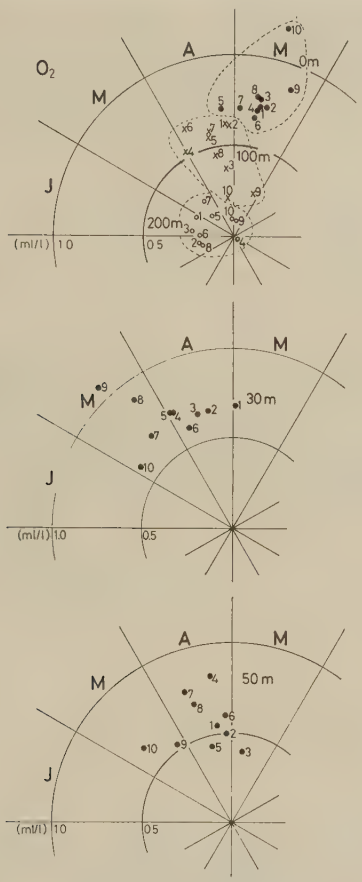

Fig. 11. Change of relation between the amplitude and the phase of oxygen content from station to station at a few selected depths.

At PM-9 and PM-10 the annual range is small in the layer at a depth of more than 100 m as well as water temperature and salinity, and this also suggests that the water originated from the deep layer occupies the shallow layer.

(C) The ratio of variance

In the previous sections the relation between the annual range and the phase was discussed. Although the annual variation of each parameter, particularly sea water temperature, was well demonstrated in the simple harmonic march, the distortion

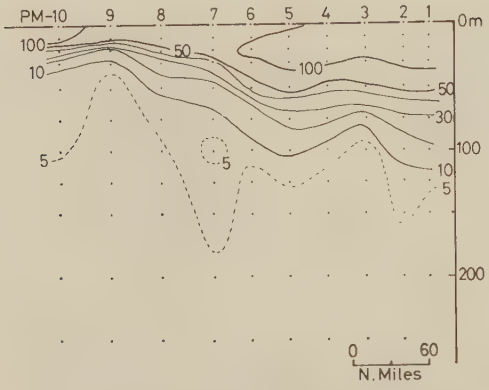

Fig. 12. Vertical distribution of the ratio of variance of water temperature.

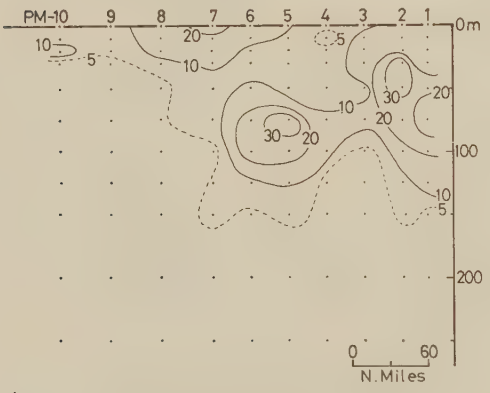

Fig. 13. Vertical distribution of the ratio of variance of salinity.

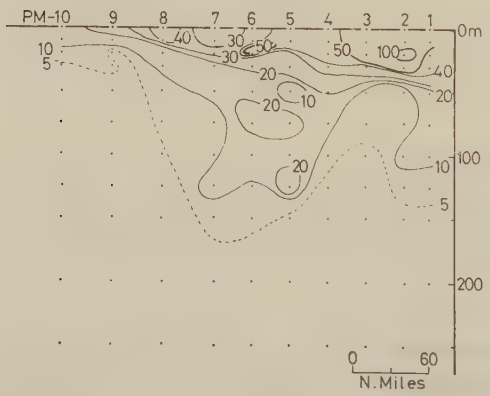

Fig. 14. Vertical distribution of the ratio of variance of oxygen content.

from the annual variation is also interesting to understand the more detailed variation.

For this purpose, the ratio of variance is introduced as follows:

$$F=\frac{(1/2)\sum_i(\hat{y}_i-\bar{y})^2}{(1/13)\sum_i(y_i-\hat{y}_i)^2} \qquad (2)$$

where $\hat{y}_i$ and y_i are the same as in the section 2 and $\bar{y}$ is the mean value of time series of observed values. By statistics as described by KUME (1971) the ratio of variance has F-distribution of the degree of freedom 2–13 under hypothesis of no annual variation. Namely, the large the ratio is, the more dominant the annual periodic variation is. This is called in terms of *stable* in statistics. The ratio of 5.0 corresponds to the level of significance of 2.5%, therefore the ratio more than 5.0 means the existence of the annual variation in percentage of probability more than 97.5%. The levels of significance of 1.0% and 0.5% correspond to 6.7 and 8.2 in F respectively. The vertical distributions of the ratio of variance are shown in Figs. 12 to 14.

(a) Water temperature (Fig. 12)

The ratio of variance of water temperature is large in the upper layer because of the influence of seasonal variation of air temperature. The isoline of 5.0 in F lies at a great depth at PM-2 and PM-7, and at a small depth at PM-9.

(b) Salinity (Fig. 13)

Although the ratio of variance of salinity is not large at the sea surface, it has large values at a depth of around 100 m. It is considered that the precipitation and coastal water disturb the simple harmonic annual variation. At a depth of around 75 m at PM-5 and 50 m at PM-2, there exists a *stable* layer of the ratio of variance more than 30, corresponding to the haline water exceeding 34.25 per mill as shown in Fig. 4. The depth of the isoline of 5.0 in F is larger to the south of PM-2, and also between PM-5 and PM-7 compared with the other parts of the section. This suggests that the water in the PM-line can be devided into four types, namely, the coastal warm water, the near coastal cold water, the Tsushima Warm Current water and the offshore cold water.

(c) Oxygen content (Fig. 14)

Near the sea surface, the ratio of variance of dissolved oxygen content is large because of the effect of the annual variation of water temperature. Except for near the sea surface there is a *stable* layer of the ratio more than 20 at a depth of around 75 m at PM-5 and PM-6, where high *stability* in the annual variation of salinity and poor oxygen content less than 5.8 ml/l are seen. The isoline of 5.0 in F also lies at a depth well corresponding to that of salinity.

Acknowledgements

The author wishes to thank Mr. Takeo TSUCHIDA and the other members of Oceanographical Division of Maizuru Marine Observatory for their helpful advices and continual encouragements.

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日本海における水温，塩分，溶在酸素量の年変動

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1973年から1976年まで各季節ごと4年間の海洋観測データを用いて，日本海の水温，塩分，溶在酸素量の年変動のようすを統計的に考察した。

年変化を単一正弦曲線と仮定し，その振幅と位相の関係を論じた。またその曲線からのずれ具合より年変化の安定性についても考察し，それらの場所による相異から日本海表層水に，沿岸の暖水，沿岸寄りの冷水，対馬暖流水，沖合冷水の4つの型があることがわかった。

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The cold water eddy observed far south of Shikoku in September 1979

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Abstract: A solitary cold water eddy was found out far south of Shikoku, near 29°30′N, 134°15′E being identified only at a depth of more than 200 m in September 1979. A similar cold water eddy was observed just above the Kinan Seamounts in August 1979. The former seems to be the same with the latter, judging from their meridional scales and thermal structures. If so, the cold water eddy is counted to move at a speed of 3 n. miles/day west-southwestward from August to September, while the warm water eddy located north of the cold one moved at a speed of 2 n. miles/day northeastward from July to September.

1. Introduction

Since 1975, the Kuroshio has continuously meandered south of Tokaido associated with the large cold water region. We observed water temperature with an expendable bathythermograph (XBT) in the warm water region south of Honshu on board R/V Keifu Maru (Japan Meteorological Agency) in September 14–19 1979. On this cruise we observed a cold water eddy which seemed to be the same as that detached from the large cold water region off Tokaido in August 1979. Such a cold eddy was observed in this area for the first time in May 1977 and named "Harukaze" (KAMIHIRA *et al.* 1978). KONAGA and NISHIYAMA (1978) suggested that the behavior of the eddy might be affected by existence of the Kinan Seamounts off the Kii Peninsula.

Here we will analyze data obtained on board R/V Keifu Maru together with other available data to examine the behavior of the cold water eddy.

2. Observation on board R/V Keifu Maru

Figure 1 shows water temperature distribution at a depth of 400 m in September 1979 together with locations of main seamounts south of Honshu and stations of XBT on board R/V Keifu Maru. According to this figure, the center of the cold water region off Tokaido is located near 33°N, 137°30′E and its lowest temperature does not exceed 6°C. Furthermore, off Shikoku we can see another cold water region whose center is seemed around at 29°30′N, 134°15′E. Its lowest temperature is 10.1°C at

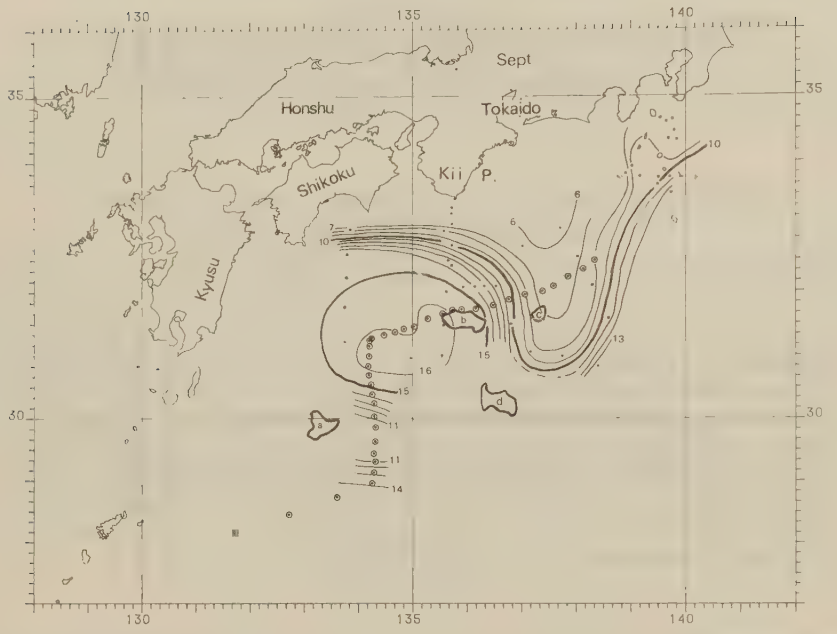

Fig. 1. Horizontal distribution of water temperature at 400 m depth in September 1979 together with locations of main seamounts south of Honshu, a: Komahashi No. 2, b: Koshu, c: Komahashi No. 3, d: Kinan. Observation stations on board R/V Keifu Maru are denoted ⊙.

a depth of 400 m.

The vertical temperature sections across the cold water regions are shown in Fig. 2. The isotherm rise can be seen little from sea surface to 200 m depth in the cold eddy south of Shikoku, while that in the eddy off Tokaido can be seen even near surface. The former seems to be smaller in horizontal scale and weaker in magnitude than the latter. Isotherms of 10, 15 and 20°C of the eddy off Shikoku rise from 630 m depth in the surrounding up to 400 m depth at the center, from 450 m depth up to 260 m depth and from 200 m depth up to 150 m depth, respectively.

3. The birth and the movement of the cold water eddy off Shikoku

Horizontal distribution of water temperature at 400 m depth in July and August 1979 is shown in Fig. 3. The isotherm of 11°C regarded as the stream axis of the Kuroshio runs south-southeastward west of the Koshu Seamount, then goes round south of the Kinan Seamounts and runs northeastward thereafter, in July. It goes round north of the Koshu Seamount, then runs northeastward after reaching 31°N, 137°E

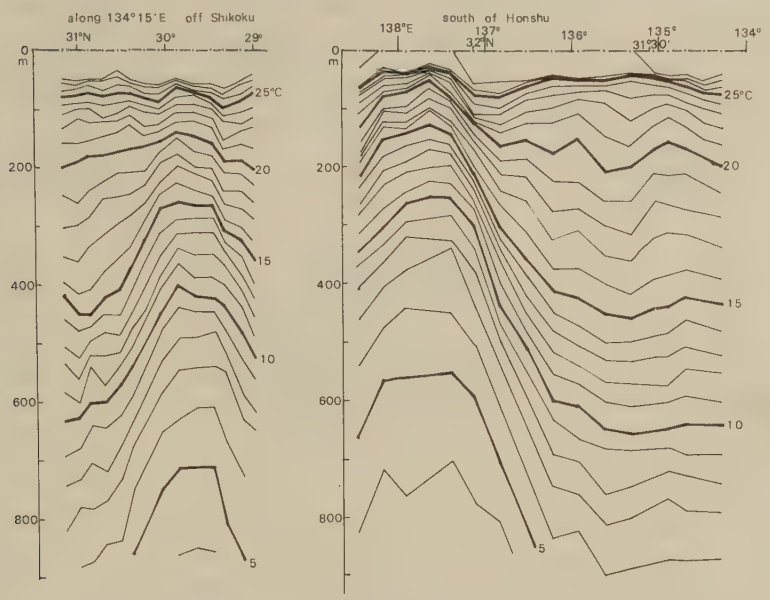

Fig. 2. The vertical sections of water temperature across cold water regions south of Honshu measured on board R/V Keifu Maru in September 1979.

in August as shown on Fig. 3. In August, we can see another circular isotherm of 11°C surrounding the Kinan Seamounts. It could be regarded as a cold water eddy just going to be detached from the cold water region off Tokaido. Its meridional breadth is about 50 n. miles and the zonal one is about twice. A similar eddy was seen staying above the Kinan Seamounts in July 1977 (KAMIHIRA *et al.*, 1978). Here let us compare the eddy in 1977 with that in present case. The lowest temperature at 400 m depth and the depth of 10°C isotherm are 6.3°C and 220 m near the center in the former and are 10.1°C and 404 m in the latter, respectively. In not only water temperature but also dimension, the latter is much weaker than the former, which has almost the same values as cold water region off Tokaido.

Judging from the lowest temperature at 400 m depth and the horizontal scale of eddies, it may be seen that the cold eddy detached in August reaches east of the Komahashi No. 2 Seamount southeast of Kyushu in September. In September, the Kuroshio goes round north of the Koshu Seamount, then flows north-northeastward after arriving at the southernmost position, 30°40′N, 137°50′E, far east-northeast of the Kinan Seamounts. The cold water eddy moves west-southwestward at a speed of 3 n. miles/day. Those movements are summarized in Fig. 4. This moving speed is

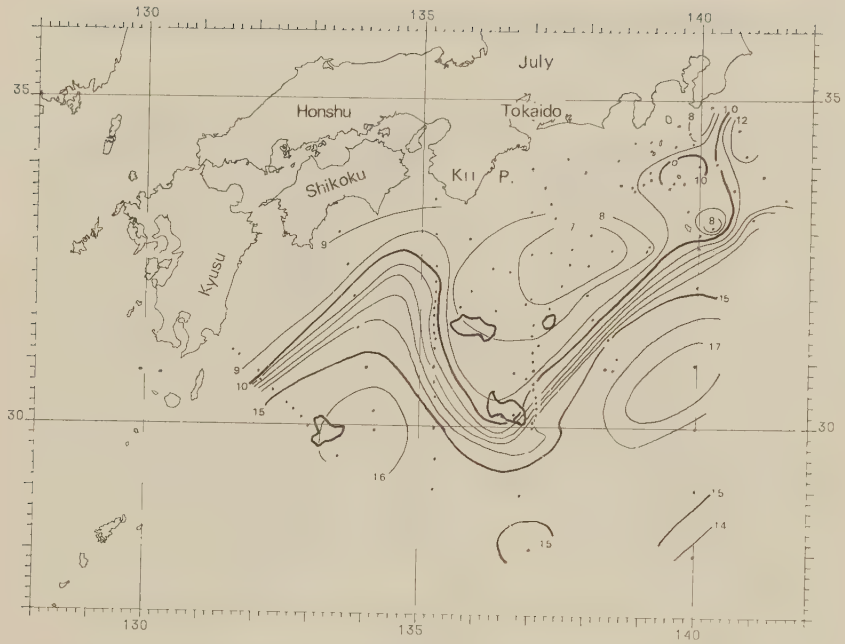

Fig. 3-1

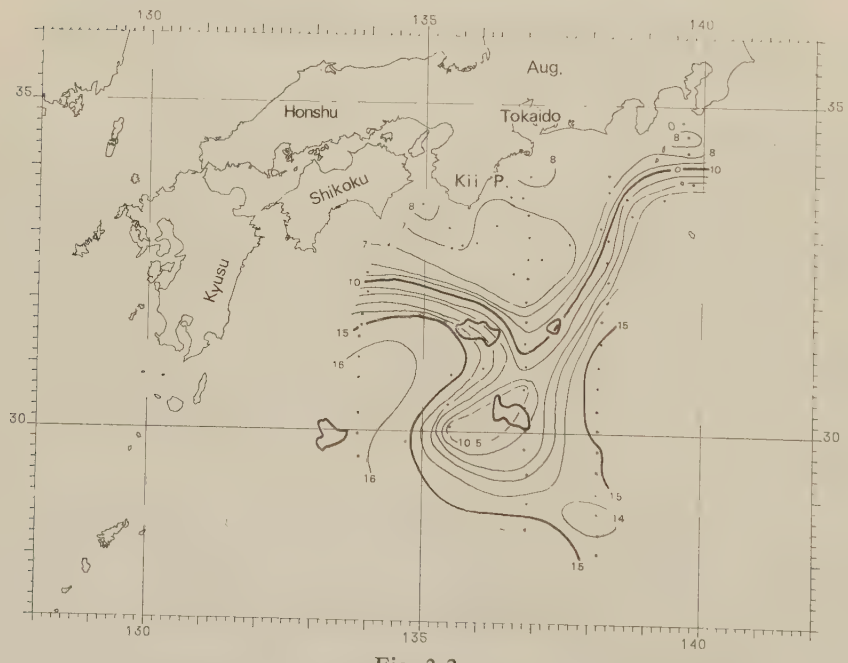

Fig. 3-2

Fig. 3. Horizontal distribution of water temperature at 400 m depth in July and August 1979.

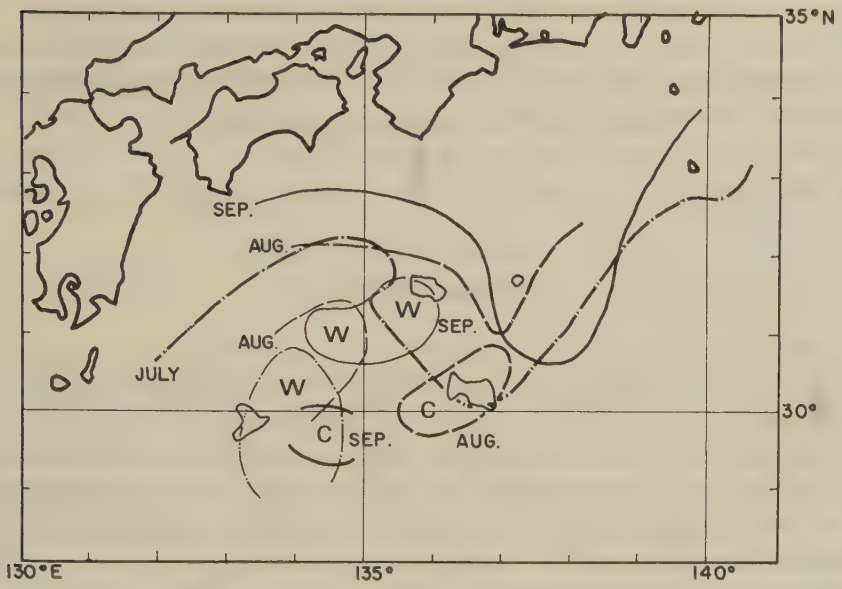

Fig. 4. The movement of the cut off eddy and that of the warm water eddy south of Shikoku in July to September 1979. Thick lines are isotherms of 11°C which show the cut off eddy and the cold water region, and thin lines are those of 16°C which show the warm water eddy.

nearly the same as that of a cold ring in the Gulf Stream region in the Atlantic Ocean (LAI and RICHARDSON, 1977).

On the other hand, the area enclosed by a isotherm of 16°C regarded as a warm eddy appears on the east of the Komahashi No. 2 Seamount in July. In August, its center is seen 70 n. miles away northeast of the Komahashi No. 2 Seamount and southwest of Koshu Seamount in September. During this period, it moves at a speed of 2 n. miles/day.

4. Remarks

The eddy reported in this article has little manifestation in the water temperature structure above 200 m depth, so that we cannot identify it from water temperature distribution at a depth of 200 m.

KAWAI (1978) describes that eddies generated east of Honshu may come and go westward south of Honshu through a break of the Izu-Ogasawara Ridge. Such eddies cannot be seen at shallower depth as a long time has elapsed after genesis.

According to the distribution of temperature at 300 m depth, KAWAI (1978) pointed

out that many of such solitary eddies existed near seamounts in the western North Pacific Ocean. Moreover recently, a small cold ring detached from the cold eddy south of Tokaido was identified in March 1979 based upon Infrared Image of the Geostationary Meteorological Satellite "Himawari" (Maritime Safety Agency, 1979). Considering these results it is thought that cut off eddies may frequently be generated around the Kinan Seamounts south of Honshu. Such events should be confirmed by further observations.

Acknowledgements

The observation on board R/V Keifu Maru was partly financially supported by Science and Technology Agency, "Kuroshio Explitation and Utilization Research" and scientific research grant defrayed by Ministry of Education, Science and Culture, "the Large Scale Meander of the Kuroshio and the Associated Cold Water Mass". The authors express their hearty thanks to Captain Masaharu MATSUNO, meteorological observers Mr. Tadakazu YAMAGATA, Mr. Yoshio MORI and Mr. Hidetoshi MATSUMOTO, and other officers and crew of R/V Keifu Maru for their kindly help in the observation.

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四国沖で観測された冷水塊

西山勝暢・小長俊二・石崎廣
（気象研究所）

1979年9月に，四国沖で 200 m 以浅の水温分布からはわからない，勢力の弱い冷水渦が，気象庁の啓風丸により観測された。この冷水渦は，東海道沖に存在している大冷水域より，紀伊半島沖にある紀南海山上で8月に切離して発生したものが，3海里/日の速さで移動してきたものと思われる。一方，この間，四国沖には暖水渦も存在していて，2海里/日の速さで北東に移動した。

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Geostrophic transport in the East China Sea and southeast of Yakushima Island—A case study

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Abstract: It is well known that there exist two typical paths in the Kuroshio south of Tokaido. Namely one is the straight path along the continental slope south of Honshu and the other is the meandered path associated with the large-scale cold water region south of Tokaido. Although the geostrophic transport of the Kuroshio at the section west of Ryukyu Islands is larger and that southeast of Yakushima is smaller in the latter duration compared with those in the other period, the clear explanation of this variation of the transport has not been succeeded.

A simple model to explain this complicated fluctuation of the geostrophic transport is introduced. In this model, the behaviors of warm and cold eddies are seemed to play an essential role to clarify the phenomena.

1. Introduction

The investigations on the total transport of geostrophic current of the Kuroshio have been intensively carried out by various authors and they have revealed that the geostrophic transport of the Kuroshio has large variation not only from location to location but also from time to time. Among those studies NITANI (1972) and KONAGA *et al.* (1980) suggested that the transport across the section in the upstream from Yakushima (see PN in Fig. 1) is larger when the Kuroshio Meander is present and smaller when absent, and *vice versa,* across the section southeast of Yakushima.

Some authors have intended to explain such complicated fluctuations of the total transport across the two sections. KAWABE (1980) proposed an idea that a northward deep current along the eastern side of the Nansei Shoto ridge, corresponding to a deep western boundary current, may develop during the periods when the Kuroshio Meander is present. During this time, the apparent geostrophic transport in upper layer across the section E might be weaker. KONAGA *et al.* (1980) pointed out that the considerably strong southward transport was observed east of Amami Oshima when the Kuroshio Meander is present in 1955 and 1959–1961. They supposed that this is a reason why the transport in the section PN and section E varies out of phase.

Recently it was also revealed that the transport across the two sections was considerably large in 1977, in spite of presence of the Kuroshio Meander.

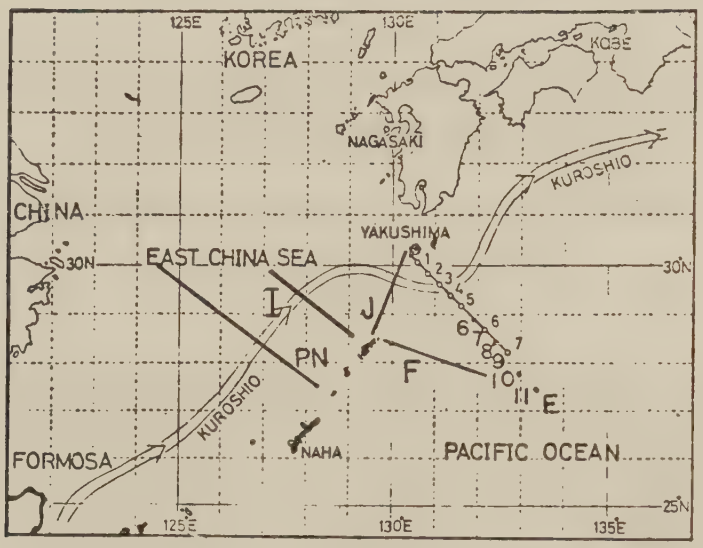

Fig. 1. Locations of the stations and typical Kuroshio path.

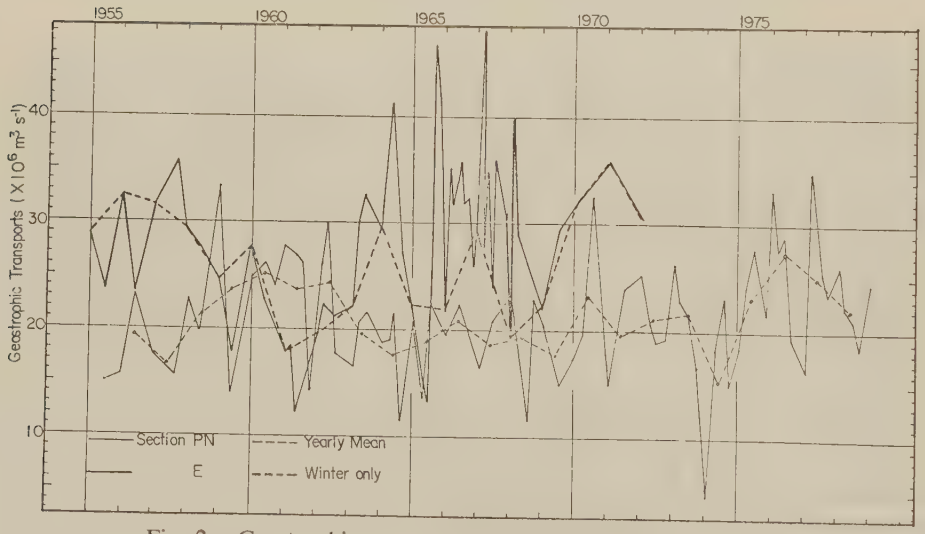

Fig. 2. Geostrophic transports across the sections E and PN.

In the followings the variations of the geostrophic transport of the Kuroshio across the two sections are summarized and a simple model to clarify the mechanism of the variation of the transport is introduced.

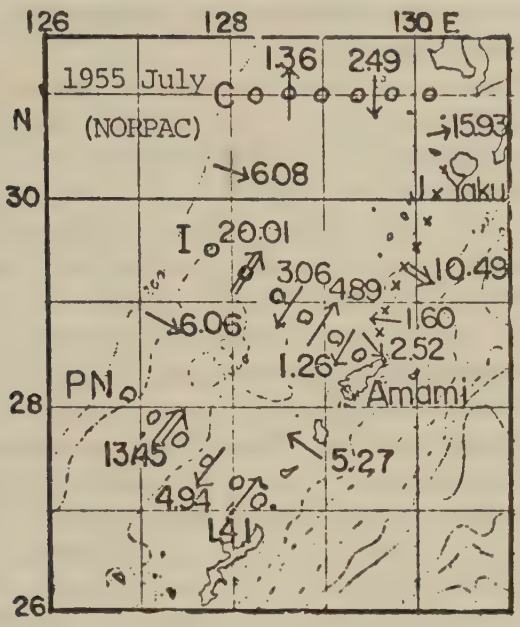

Fig. 3. A budget of geostrophic transport in the East China Sea in July 1955. (in 10^6 m^3/s).

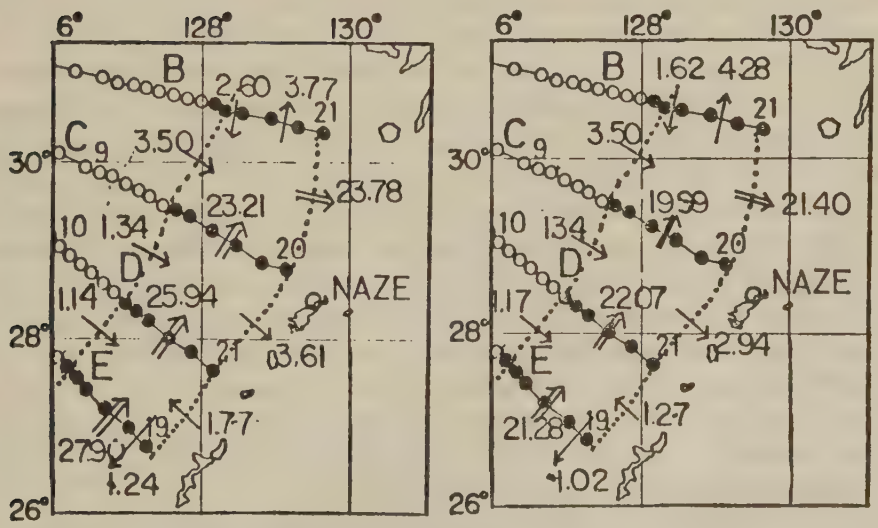

Fig. 4. A budget of geostrophic transport in the East China Sea in October 1968. Left; referred to bottom and right; to 700 db. (in 10^6 m^3/s).

2. Summary of the geostrophic transport of the Kuroshio across the two sections

2.1. Time-series of total transport

Locations of the sections and typical Kuroshio flow path are depicted in Fig. 1. The geostrophic transport from 1955 to 1979 is shown in Fig. 2 (referred to 700 db in the East China Sea and 800 db in the North Pacific). It is known that during this period, the Kuroshio Meander was observed in 1955, 1959–1963 and 1975 to the present (NISHIYAMA *et al.*, 1980). Data in the section E after 1972 are not available. The geostrophic transport in each individual case fluctuated considerably. However, across the section PN it was remarkably large, on average, when the Kuroshio Meander was present, and *vice versa,* across the section E, as reported by NITANI (1972).

2.2. Geostrophic transport in the East China Sea

The section PN is located northwest of Okinoerabujima and extends to the shallow part above the continental shelf. The Kuroshio flow north-northeastward across the section along the continental slope. In Fig. 3 the budget of the geostrophic transport in summer 1955 is shown when the Kuroshio Meander was present since 1953. The figure suggests that the northward transport is supplimented by water from both the continental shelf and the North Pacific. Northward transport across the section PN which seems to be small is considerably intensified by such inflows as measured at section I. Figure 4 shows another example of the budget of the geostrophic transport in October 1968, when the Kuroshio Meander was absent. The observations were made nearly simultaneously under the cooperative survey with the five research vessels belonging to the Japan Meteorological Agency as a part of the CSK project. Compared with the previous measurements given in Fig. 3 the stream axis of the Kuroshio had migrated eastward from the continental slope in the East China Sea. In the left chart of Fig. 4, the transport referred to the bottom is given. The geostrophic transport seems to decrease gradually toward the north with decreasing depth of the bottom. This situation suggests a deep countercurrent across the southern sections, or an increment of the barotropic component across the northern sections. In the right chart of Fig. 4, the reference level is taken at 700 db and rather similar transports are seen in each section. Figures 3 and 4 indicate that the transport toward the Japan Sea is very small. Though there are many uncertainties in estimating the geostrophic transport, partly due to the transport on the continental shelf and partly due to the uncertainties of the reference level and/or the barotropic component, we can conclude that most of the flux across the section PN and the inflow from continental shelf must flow out eastward into the North Pacific across section J in Fig. 1.

2.3. Budget of the transport around the section E

In Fig. 5, we show ten cases of the budget of the geostrophic transport in the vicinity of section E, southeast of Yakushima. It is also revealed from this figure that the

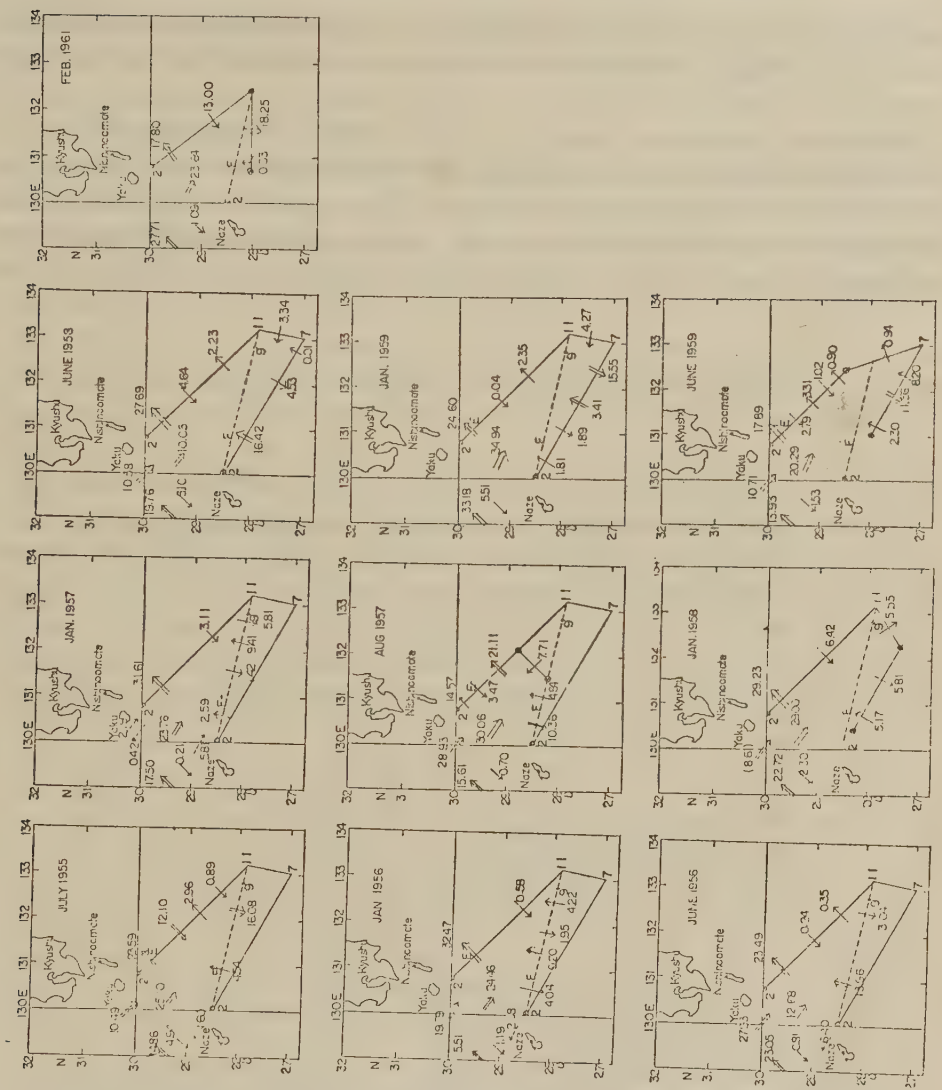

Fig. 5. Budgets of geostrophic transport around the section E from 1955 to 1961. (in 10^6 m^3/s).

geostrophic transport across the sections PN and E changes out of phase on the whole. A basic question why the transport across the section E is required to decrease when that across the section PN increases, is partly answered from these figures. That is to say, considerably strong southward flows across section F (see Fig. 1), are seen in 1955, 1959 and 1961 when the Kuroshio Meander was present. However, in the other

years there were northward flows across this section, which combined with the Kuroshio across section J and flow together northward across the section E, as stated earlier by KONAGA *et al.* (1980).

Unfortunately hydrographic data in the section E are not available after 1972, so we use the data of nearby sections to calculate the transport from 1975. In Fig. 6, six cases are shown over the period from 1977 to 1979, when the Kuroshio Meander moved anomalously west and extended to the south, and the transport across the section PN was remarkably large as shown in Fig. 2. The transport across the section slightly

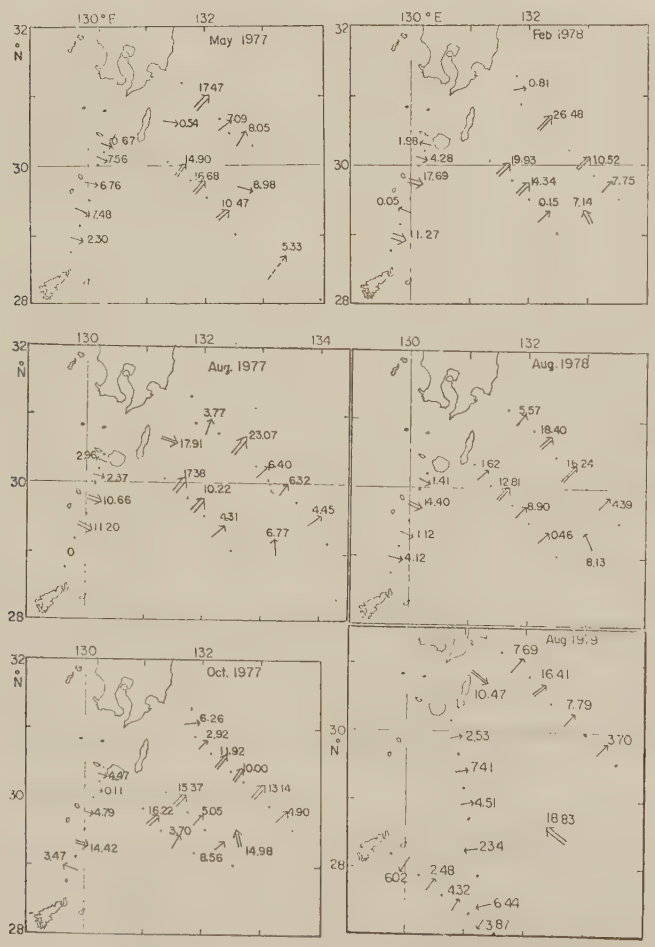

Fig. 6. Budgets of geostrophic transport east of the Straits of Tokara, 1977 to 1979. (in 10^6 m^3/s).

north of the section E was considerably large in contrast to those in Fig. 5, except in 1979 when the Kuroshio Meander had moved northeastward.

3. A schematic model of clarification

From Figs. 5 and 6, we may describe some schematic models of the position and the strength of the Kuroshio Meander, relating to the position and strength of anticyclonic quasi-stationary eddy located south of Honshu in Fig. 7. This warm eddy can be thought to have an influence upon the transport estimations south of Yakushima.

We may explain Fig. 7 briefly.

(1) When the Kuroshio Meander is absent, it is clear from the observations that the northward flow along the east side of Nansei Shoto joins the flow from the East China Sea across the Straits of Tokara, so that the transport south of Yakushima is enhanced.

(2) When the Kuroshio Meander is present, as in 1955, 1959–1963 and 1979, due to the westward migration of the warm and cold core eddies arranged south of the Kuroshio, the northward current moves to the location west of Nanseishoto and forms an anticyclonic circulation around Amami Oshima and others. Then a part of this increased northward transport may return southward along the east side of the ridge and little is added with northward current across the section E.

(3) When the Kuroshio Meander moves further west and extends southward, the

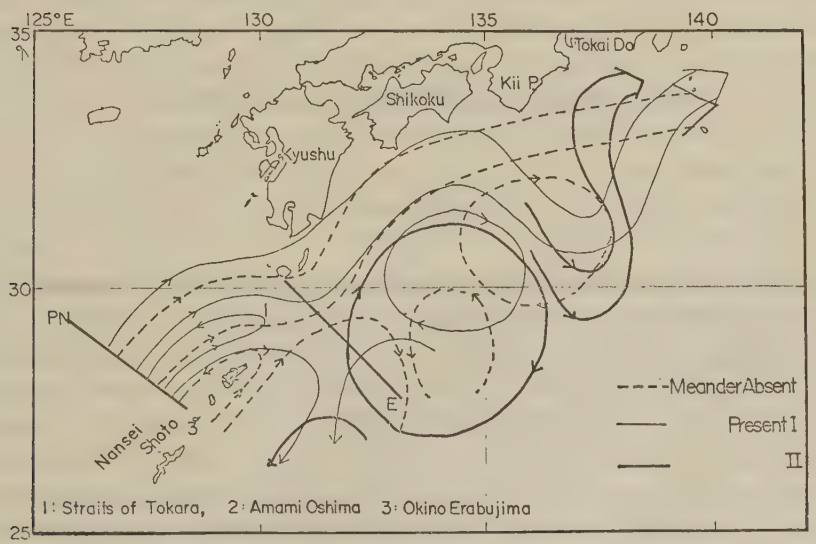

Fig. 7. Schematic model of the current patterns in each case.

warm core gyre also moves west and enlarges. Hence the section E must be affected by the northward current at the western portion of the large anticyclonic eddy south of Shikoku and the transport across the section E may become considerably large.

Though the model presented here is partly based upon the published atlas of the geopotential topography (*e.g.* Japan Oceanographic Data Center, 1967; NISHIYAMA *et al.*, 1980), well-planed observations to detect the validity of the model will be expected in the future studies.

Acknowledgements

The authors wish to express their hearty thanks to Messrs Katsumi TANIOKA and Yoichi HANZAWA of the Nagasaki Marine Observatory, for their useful advice.

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東シナ海と屋久島南東線上での流量について

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さきに1972年以前のデータを用いて，筆者らは屋久島南東線の地衡流について考察を加えた。その際，屋久島南東 E 線と東シナ海 PN 線の流量が，東海道沖に冷水域が存在するか否かによって，その増減が逆位相に変化することの機構を考えた。しかし，最近の資料から，東海道沖に冷水域が存在するときに，E 線の近くで流量が増大していることがわかった。KAWABE (1980) は，冷水域が存在しているときに南西諸島沿いに深海西岸境界流が発達することによる E 線の見かけの流量変動を示唆した。筆者らは，東海道沖に冷水域が発生し発達するいろいろな段階に応じて，黒潮の南に並んでいる高気圧性暖水域や小さい低気圧性冷水渦の位置関係によって，流量の増減を定性的に表わした図を作成した。これによれば，PN 線と E 線の流量が逆位相で変化することも，また場合によっては両者とも増大することがあることもわかる。

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NOTE

The standard deviations of monthly mean sea surface temperature in the western North Pacific

Oceanographical Division
Japan Meteorological Agency

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The standard deviations of monthly mean sea surface temperature in the western North Pacific Ocean were prepared based upon the data obtained from the Ten-Day Marine Report during the years 1951–1975. This brief note is intended to introduce the newly prepared standard deviations in form of chart from January through December.

Recently requirements for information on marine environment have been increasing year by year in the various field such as shipping, fishery industries, ocean engineering, and supporting meteorological, climatological and oceanographical studies. Among them sea surface temperature is the most important parameter. Even by applying the modern observation techniques such as satellites, at present nothing but sea surface temperature is measured so frequently all over the globe as to make a routine analysis on real/semi-real time basis possible. It is general that many users need not only the absolute values of sea surface temperature but also the degree of deviation from their long-term means, which are called as "normals". Since 1949 the Japan Meteorological Agency has been providing the anomaly chart of ten-day/monthly mean sea surface temperature in the Ten-Day Marine Report for the latter requirements. The comparison of anomalies with standard deviations is useful and essential to discuss the variation of sea surface temperature. The Japan Meteorological Agency has already prepared the standard deviations of the monthly mean sea surface temperature in the western North Pacific Ocean in digital form (Japan Meteorological Agency, 1976). They were made based upon the data during the years 1956–1970. Although the statistics were intended to cover the whole region of the western North Pacific bounded by 10° and 53°N in latitude and by 110°E and 180° in longitude, no reliable values were available in the Sea of Okhotsk and the Sea of Japan.

Newly computed standard deviations were obtained with processing of the monthly means at the center of one degree square of latitude and longitude from 1951 through

1975. The statistics were made over the same waters as in the previous studies. The details to obtain the individual monthly mean sea surface temperature from the Ten-Day Marine Report and their normals were already given in the earlier article (Oceanography Division J.M.A., 1979). Standard deviation defined as

$$\sqrt{\frac{\sum_{i=1}^{n} (\overline{T_i - \bar{T}})^2}{n-1}},$$

where T_i is individual monthly mean of sea surface temperature, $\bar{T}$ normal and n number of data, is prepared in the square where the number of data of monthly means are more than 4. However, the values which based upon the monthly mean data in the square where number of data is less than 15 were treated merely as reference. They are given on charts by isopleths at intervals of 0.25°C and isolines based upon reference values are given in dotted line.

Although it is out of the scope of this note to discuss the details of those charts, some characteristics are briefly summarized in the following. The maximum of deviations in the whole western North Pacific is generally seen in the sea east of Hokkaido and Sanriku-District of Honshu bounded by longitude of 150°E in each month. Above all in March and April they exceed 2°C. The standard deviations more than 1°C are limited in the marginal seas such as the Sea of Okhotsk, the Sea of Japan, the northern part of the Eastern China Sea, and the zonal waters centered at 40°N where oceanic polar front exists. In the sea south of 20°N and the sea north of 50°N it is very seldom that they exceed 0.5°C.

Fig. 13 shows the annual march of the standard deviations in the 16 selected areas. It is difficult to find out some clear seasonal trends. In the waters south of Japan and the Eastern China Sea the standard deviations are slight larger in the months from January through April than those in the other months. On the other hand, in the north-east portion of the waters in the present study, they are larger from August through November. And in the sea east of Honshu and Hokkaido they are smaller in summer season. Some large values in the northern part of the Japan Sea and the northern part of the Eastern China Sea might be unreliable due to insufficiencies of data.

The preparation of the new standard deviations presented here was carried out by Messrs Koichi Nagasaka and Iwao Nishimori in the Oceanographical Division of the Marine Department and their services are heartly appreciated.

Fig. 1. through 12. The standard deviations of the monthly mean sea surface temperature in January through December. (The scale of the chart is the same as that of normal (Oceanography Div. J.M.A., 1979).)

Oceanographical Division: Standard Deviation of Monthly Mean Sea Surface Temperature

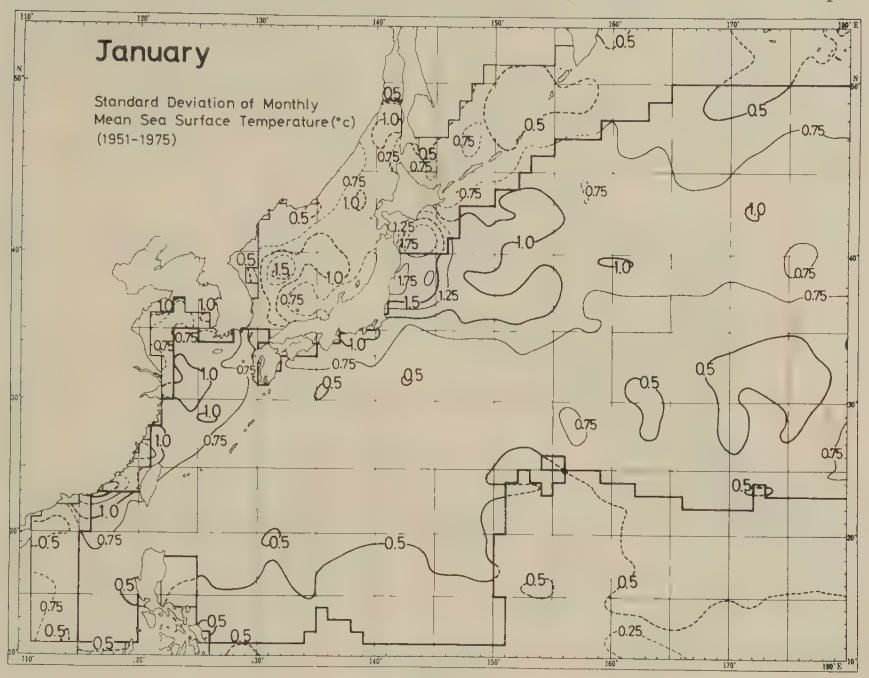

Fig. 1

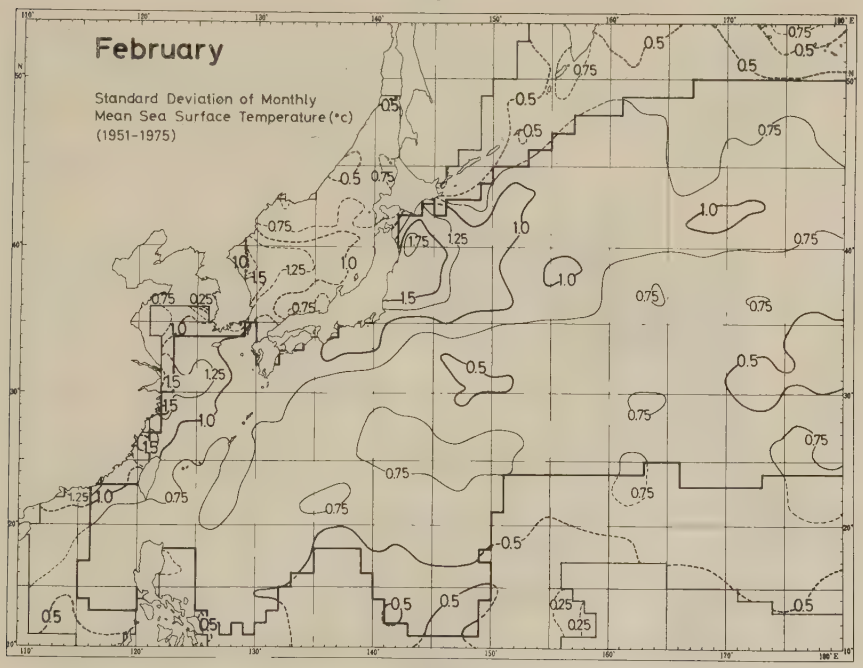

Fig. 2

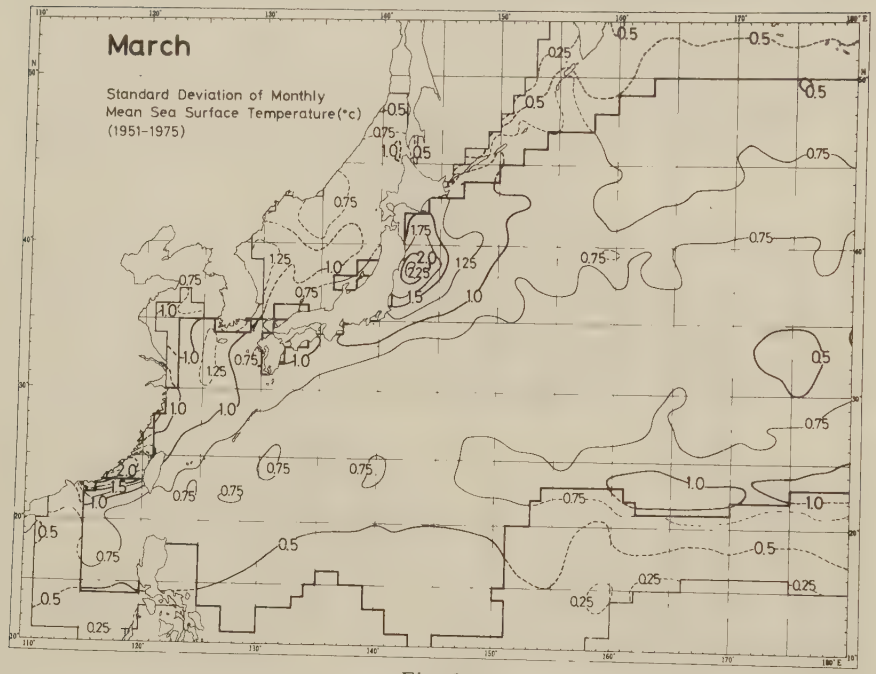
March
Standard Deviation of Monthly
Mean Sea Surface Temperature(°c)
(1951-1975)

Fig. 3

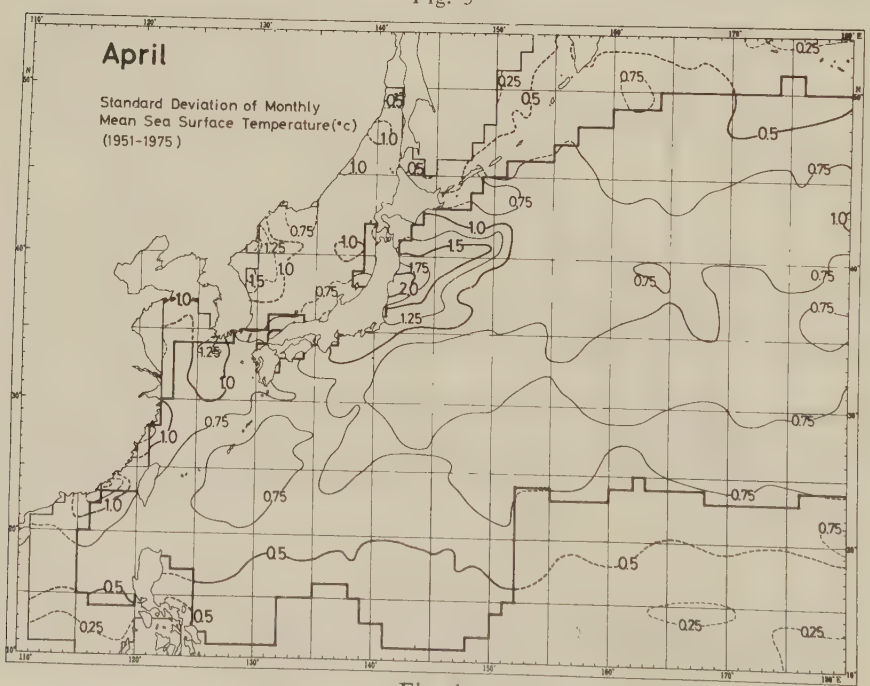
April
Standard Deviation of Monthly
Mean Sea Surface Temperature(°c)
(1951-1975)

Fig. 4

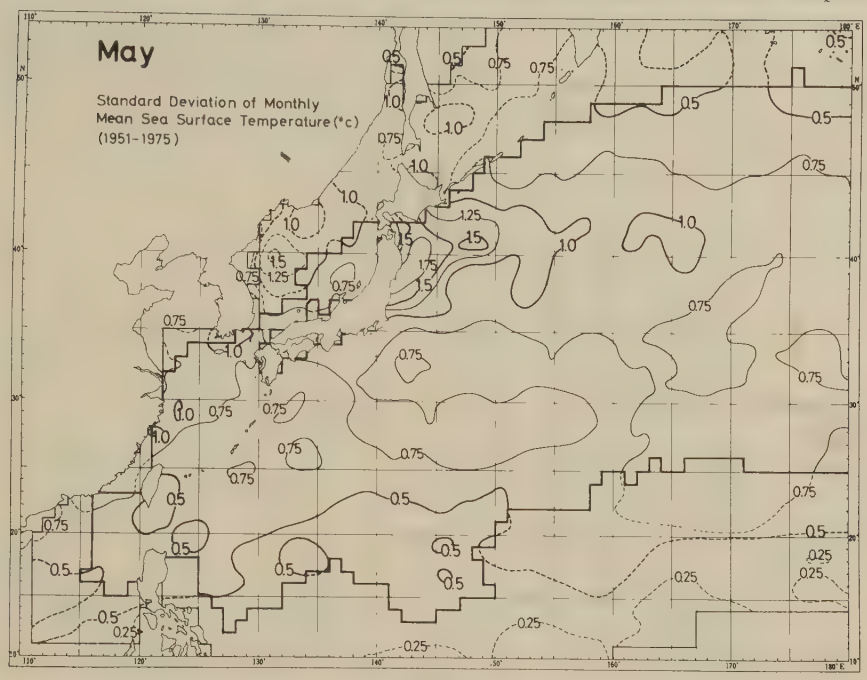
May
Standard Deviation of Monthly
Mean Sea Surface Temperature (°c)
(1951-1975)

Fig. 5

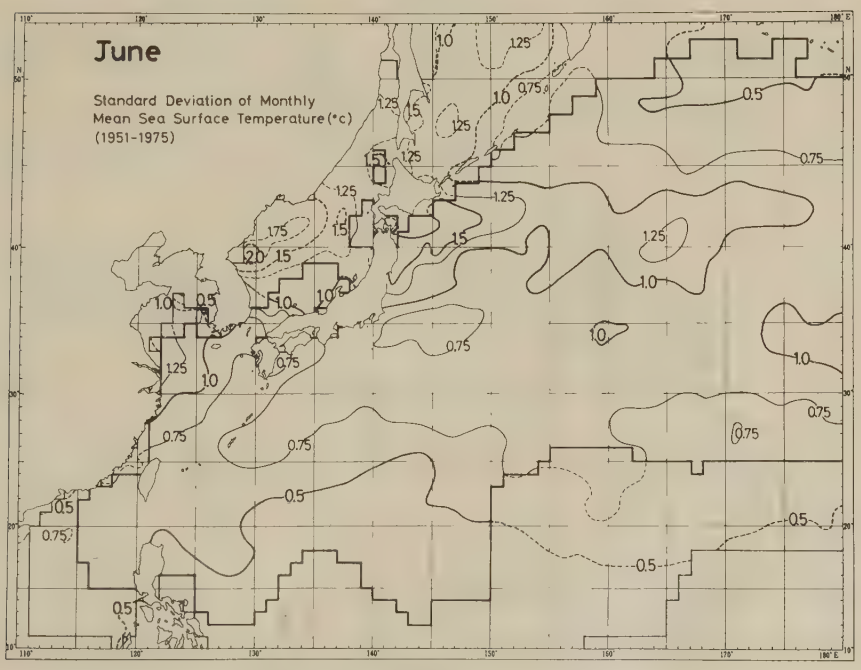
June
Standard Deviation of Monthly
Mean Sea Surface Temperature (°c)
(1951-1975)

Fig. 6

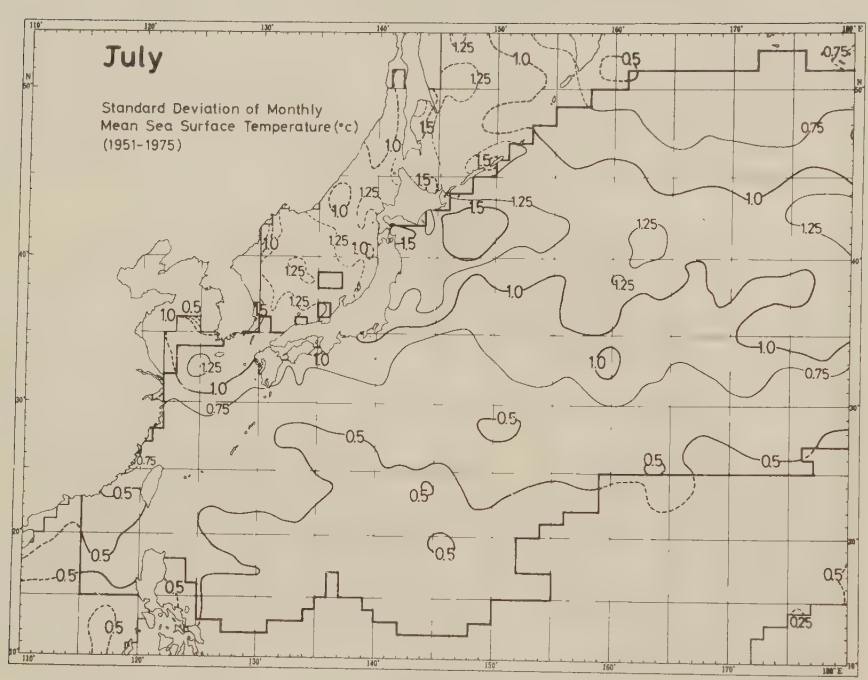
July
Standard Deviation of Monthly
Mean Sea Surface Temperature (°c)
(1951-1975)

Fig. 7

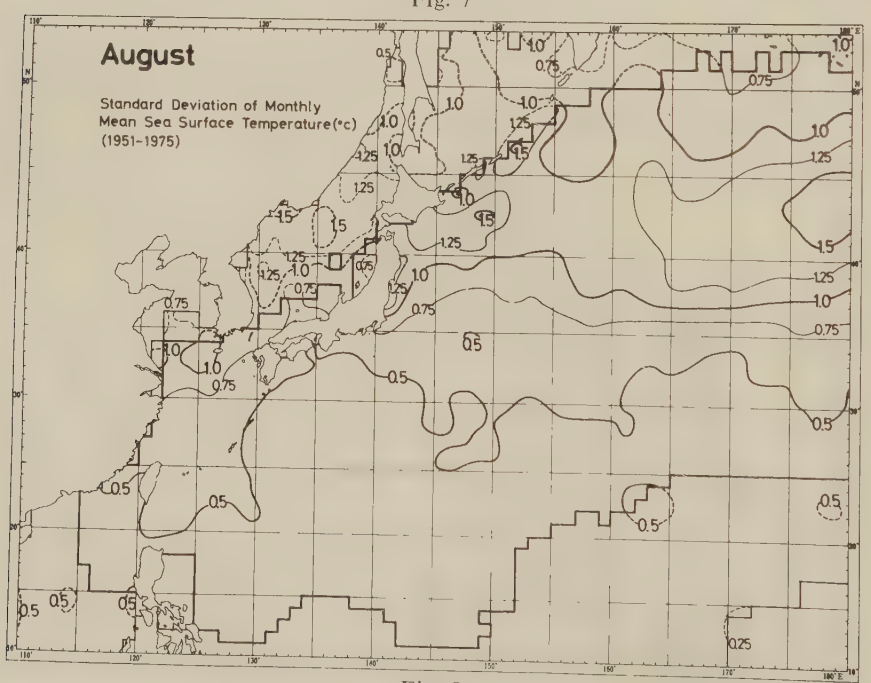
August
Standard Deviation of Monthly
Mean Sea Surface Temperature (°c)
(1951-1975)

Fig. 8

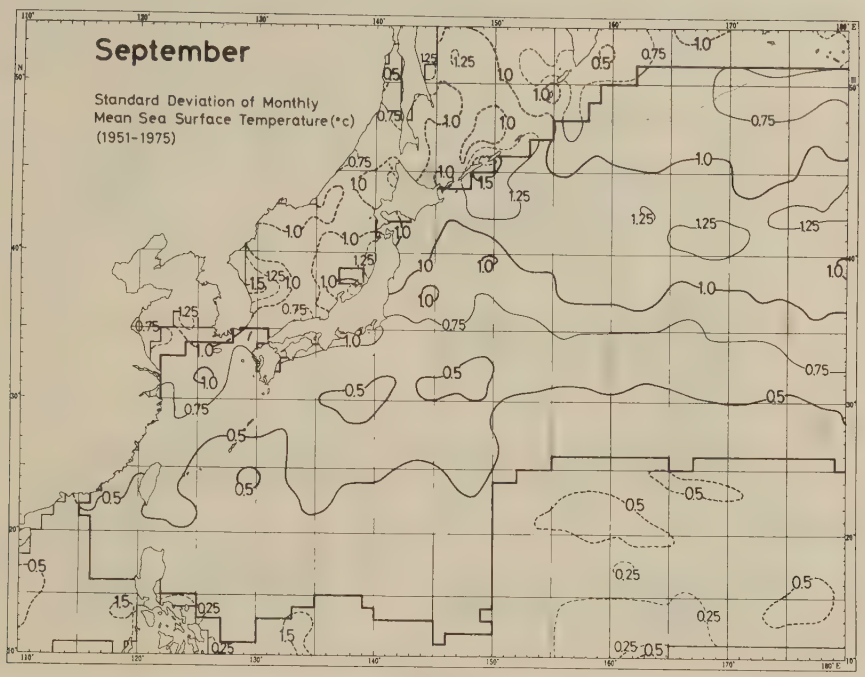
September
Standard Deviation of Monthly
Mean Sea Surface Temperature (°c)
(1951-1975)

Fig. 9

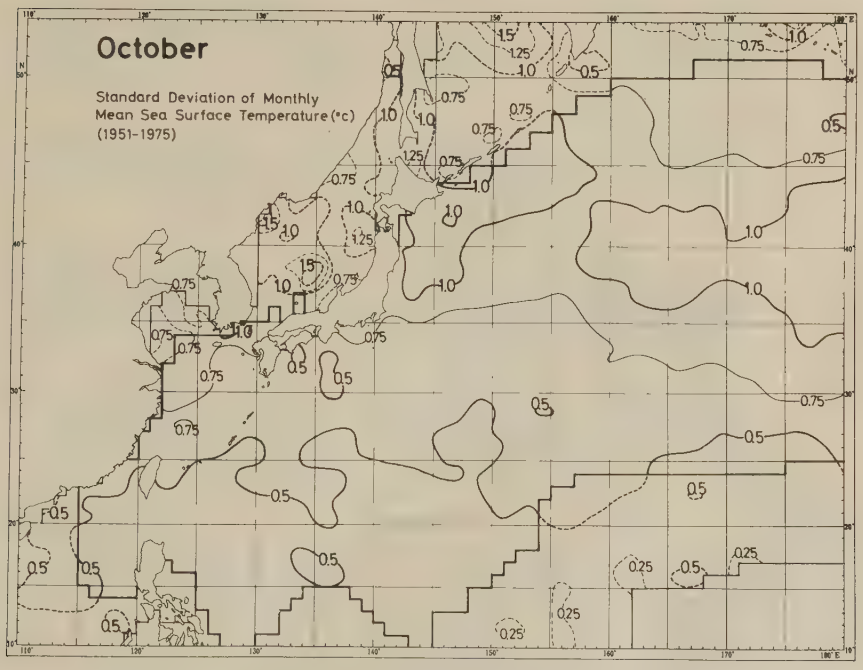
October
Standard Deviation of Monthly
Mean Sea Surface Temperature (°c)
(1951-1975)

Fig. 10

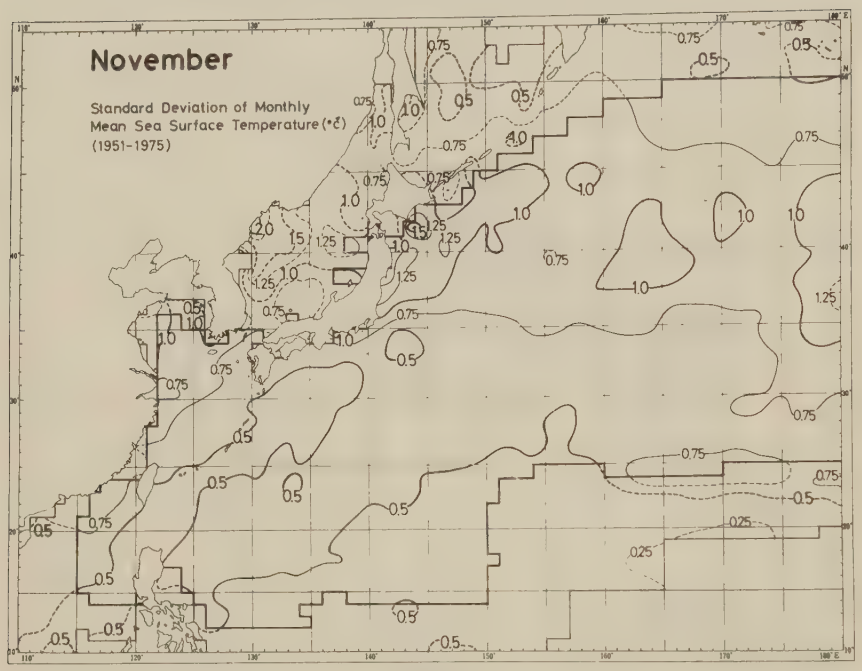
November
Standard Deviation of Monthly
Mean Sea Surface Temperature (°C)
(1951-1975)

Fig. 11

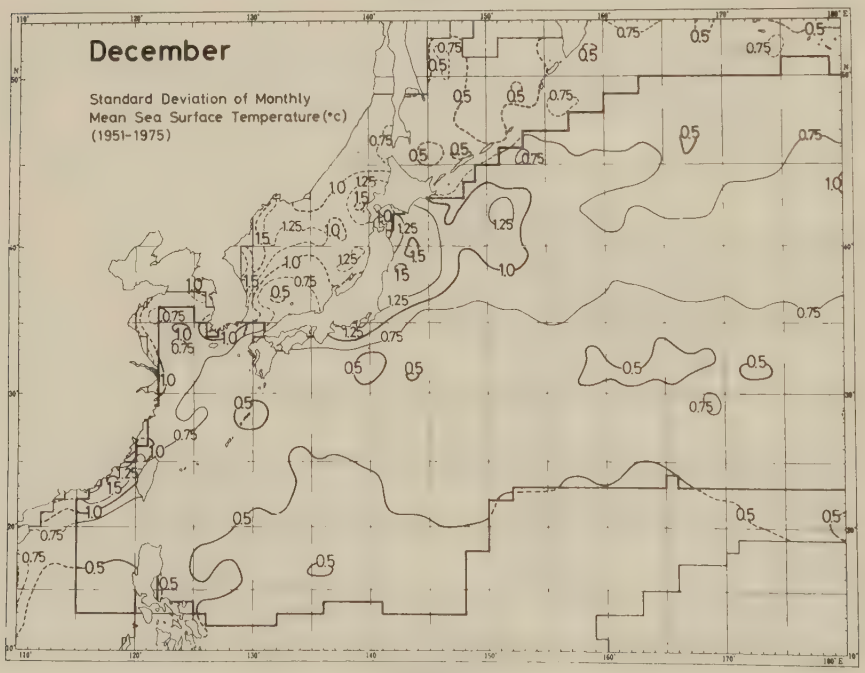
December
Standard Deviation of Monthly
Mean Sea Surface Temperature (°C)
(1951-1975)

Fig. 12

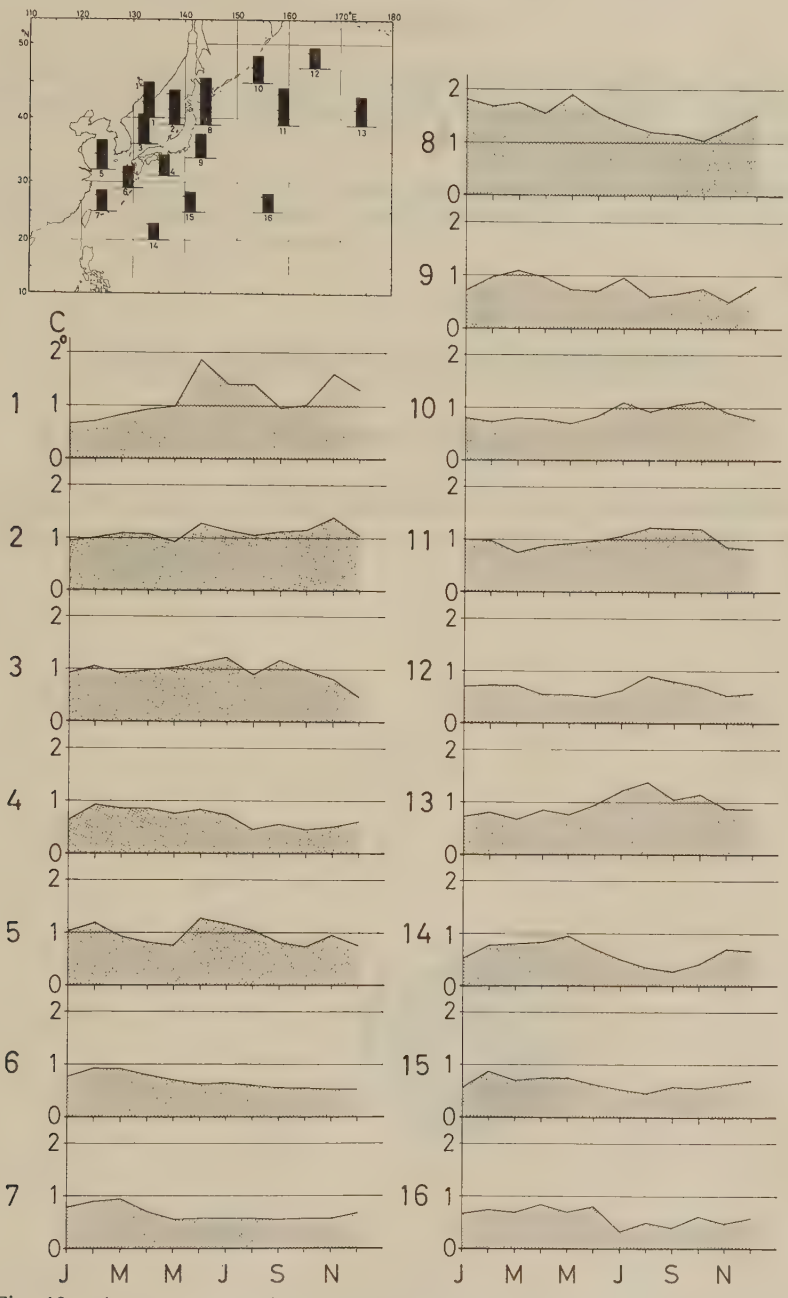

Fig. 13. Annual march of the standard deviations averaged over the square of 2° in Lat. × 2° in Long. in the 16 selected areas. The height of each bar in the chart indicates the annual means of them.

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西部北太平洋における月平均海面水温の標準偏差

気象庁海洋気象部海洋課

気象庁全国海況旬報に掲載されている旬平均海面水温図をもとに，25年間（1951～1975年）の月別海面水温の標準偏差を求めた。対象海域は10°～53°N・110E～180°で緯経度1度桝目毎に統計した。

気象庁

欧文海洋報告

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CONTENTS

ASAOKA, O.: Distribution of *Melosira sulcata* (EHRENBERG) KÜTZING, a diatom species, in the seas west of Japan 1

KANO, Y.: The annual variation of the temperature, salinity and oxygen content in the Japan Sea 15

NISHIYAMA, K., S. KONAGA and H. ISHIZAKI: The cold water eddy observed far south of Shikoku in September 1979 27

KONAGA, S., K. NISHIYAMA and H. ISHIZAKI: Geostrophic transport in the East China Sea and southeast of Yakushima Island—A case study 33

Note

Oceanographical Division, Japan Meteorological Agency: The standard deviations of monthly mean sea surface temperature in the western North Pacific 41

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